MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

VOLUME 73.

THE BIHAR-NEPAL EARTHQUAKE OF 1934. BY OFFICERS OF THE GEOLOGICAL SURVEY OF INDIA.

SEISMOMETRIC STUDY. BY S. C. ROY, D.Sc., *Burma Meteorological Department.*

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(COMPILED BY A. M. N. GHOSH.)

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PART I.—DISCUSSION OF THE EARTHQUAKE.

CHAPTER I.
INTRODUCTION.
(J. A. DUNN.)

Distribution and severity of the shock.

The earthquake, which is to be discussed in this memoir, commenced between 14 hours 13 minutes and 14 hours 14 minutes, Indian standard time on the 15th January 1934, and continued to be felt during a period of 5 minutes in the central tract. The area of greatest devastation was in North Bihar and Nepal, but damage of gradually diminishing intensity extended into adjacent provinces.

Within three minutes Monghyr and Bhatgaon were in ruins, as also were large parts of Motihari, Muzaffarpur, Darbhanga, Katmandu and Patan, whilst in Sitamarhi, Madhubani and Purnea houses had tilted and sunk into the ground. In Purnea 95 per cent. of the houses were said to be uninhabitable and 50 per cent. destroyed. Across the Ganges, damage in such towns as Patna, Barh and Jamalpur was severe, the roads were choked with bricks in places, as at Jamalpur, and sections of the bazaar collapsed. Serious damage took place so far afield as Darjeeling and other places in Bengal.

Within the limits of the Indian Empire the shock was felt over a distance of up to 1,000 miles from the central tract by persons

as far as Peshawar in the north-west, Fort Hertz in the east, Akyab in the south-east, Bezwada and Ongole in the south and Bombay in the south-west. In a northerly direction, beyond Nepal, no reports have been available as to the distance the shock was sensible to man, but pilgrims in Katmandu reported its occurrence at Lhasa. It was felt over an area of approximately 1,900,000 square miles (4,920,000 square kilometres) in India and Tibet, and accordingly the Bihar shock ranks in intensity with any similar catastrophe that has taken place in historic times.

In general the shock went unnoticed in South Bombay Presidency, South Madras Presidency and in Mysore but along a narrow strip of the west coast, in Travancore and South Kanara, slight movement was reported. A slight shock was also reported near Moulmein in Lower Burma.

The shock was recorded in most of the seismological stations of the world; according to reports the earthquake bell at the West Bromwich Observatory, England, stopped as a result of the intensity of the movement. In India the shock was so strong that none of the seismographs in Calcutta, Agra or Dehra Dun was able to make a complete record of the earth waves. At Colaba in Bombay the earthquake was fully recorded only by the east-west component of the Ormori-Ewing instrument; the recording mechanism of the north-south component failed to register after the incidence of the secondary waves. A record from Oorgaum, in South India, is more complete.

Loss of life was almost entirely confined to the central area; the deaths reported were distributed as follows:—

Muzaffarpur town	956
Muzaffarpur district	1,583
Darbhanga town	310
Darbhanga district	1,839
Monghyr town	1,260
Monghyr district	237
Champaran district	499
Saran district	193
Bhagalpur district	174
Patna district	142
Gaya district	34
Shahabad district	22
Purnea district	2
Santal Parganas	2

It is possible that a few additional casualties were not reported. In the Nepal Valley the deaths numbered about 3,400 or a little over one per cent.; in other parts of Nepal many deaths were caused by people being overwhelmed by rock falls. It is a fortunate circumstance of this earthquake that the known death roll of 7,253 in India, although great, is not in proportion to the damage done to property. Two factors contributed to this comparatively low mortality: the shock took place in the early afternoon at a time when most people were awake, and many were out of doors and the shock did not reach its greatest intensity until some two and a half minutes after its commencement, so that many people had time to rush out into the open. Comparisons have been made between the intensity of this earthquake and of the later Quetta catastrophe in 1935, on the score of mortality. In both cases parts of towns were wiped out and there is little doubt that although over a small area the Quetta earthquake attained the highest intensity of the Bihar shock, in north Bihar this high intensity covered at least, with the Assam 1897 earthquake, an area which has not perhaps been exceeded and seldom equalled.

News of the earthquake reached Calcutta on the same day, more particularly with reference to Darjeeling, but for a day or so the extent of the damage in north Bihar was not appreciated. Over a large area roads were badly damaged, railway tracks were completely destroyed, and telegraph and telephone communications were entirely dislocated. The magnitude of the disaster in the central tract of north Bihar became known as a result of aerial surveys undertaken by the Bihar Government and by private enterprise. Severe damage was so widespread, however, that it was not possible to say which was the epicentral tract, and it was only after two months, when the geological survey had indicated the trend of the isoseismals, that the position of the epicentral region could be delineated.

Geological Survey investigation.

Immediately the serious nature of the earthquake became evident the Geological Survey of India commenced preparations for the examination of the devastated area. Dr. J. A. Dunn, Mr. J. B. Auden and Mr. A. M. N. Ghosh were deputed to investigate the central devastated area in Bihar and Nepal—the Nepal region being

undertaken by Mr. J. B. Auden alone. Mr. D. N. Wadia was deputed to investigate the outlying areas in northern and western Bengal. Immediately after the earthquake a copy of a standard questionnaire was published in the various Indian newspapers, calling for public co-operation in reporting the effects of the earthquake, and, in addition, a standard questionnaire, Table 1 was circulated, first to the most affected parts of India and subsequently to the more distant parts and to Burma

The three officers working in north Bihar continued their investigations until April. Mr. Auden worked mainly in the central and northern parts of the damaged area in Bihar and in Nepal; Mr Austin Ghosh worked in the central and western part of the area; whilst Dr. Dunn, besides traversing the central zone, investigated the eastern and southern parts of the damaged area. By overlapping to some extent the individual investigations were closely compared and a precise isoseismal map of the central region emerged; the absence of any serious differences of opinion in the delineation of the isoseismals, drawn to a large extent individually, is an indication of the confidence which the authors have in it.

At the commencement of the investigation the three officers deputed to the central tract met in Patna and, after a survey of the damage there, decided on the value they would attach to the several types of damage on the lines of the Mercalli scale, so that at the outset a uniform scale in estimating intensities for this area was determined. In addition, those features which it was apparent required particular investigation in this earthquake were noted, such as fissuring and widespread emission of water and sand. Every opportunity was also taken to allay local anxiety of the possible repetition of severe shocks. Large areas had to be covered in as short a time as possible, by motor car wherever practicable, otherwise by cart or on foot. Considering the widespread damage to roads it speaks well for the local assistance rendered that the work was completed in such a short time one of the authors drove 7,000 miles in the affected area in two months.

Immediately the field work was completed, preliminary reports were submitted to the Governments concerned. Mr. D. N. Wadia submitted his report on Darjeeling and Western Bengal to the Government of Bengal during March. The preliminary report on Bihar by Dr. J. A. Dunn and Messrs. J. B. Auden and A. M. N.

Ghosh was submitted to the Government of Bihar and Orissa in early May, and Mr. Auden's report on Nepal was submitted to the Government of Nepal in June.

The object of these reports was not to give a scientific description of the earthquake, but to advise the Governments concerned on several fundamental questions of reconstruction, from the point of view of both private and public buildings. The report to the Government of Bihar and Orissa was published soon afterwards by the latter Government, apparently with the object of making more widely known to the public the measures for reconstruction which the Geological Survey officers had recommended.

In the meantime short popular articles describing the earthquake had appeared in several of the Indian papers, from the pen of some of the Geological Survey officers at headquarters.

Subsequently Messrs. Auden and Ghosh, in the absence of Mr. Wadia on field work in Kashmir and of Dr. Dunn on leave, wrote a preliminary report for publication in the *Records of the Geological Survey of India*, vol. LXVIII, pp. 177-239, (1934). Their report summarised the results of the field investigation, and, in the construction of a complete isoseismal map, they utilised the very numerous replies submitted from all over India and Burma to the questionnaire issued by the Geological Survey.

The object of the present memoir, written after the lapse of some 2½ years, is to give a more complete account of the catastrophe from its geological aspect as it appears in more lengthy retrospect. There is one part of this study of earthquakes which the four geological officers concerned felt would be much wiser left to the pen of a specialist, and we were indeed grateful to secure the services of Dr. Roy to undertake the chapter on Seismometry. We believe that Dr. Roy's contribution will help this memoir to assume a more authoritative note.

It is of interest to record here that Dr. Roy, being in Rangoon, wrote his chapter without the opportunity of discussing our viewpoint with us. Our writing was practically completed at the end of 1936, his arrived in the latter part of 1937. It was most gratifying to find how closely Dr. Roy's independent results so completely agreed with our conclusions. We had scarcely expected such close confirmation of each other's work. His position of the epicentre, for example, is well within the areal limits expected by us.

Acknowledgements.

In concluding this Introduction we would like to express our thanks to His Highness the Maharaja of Nepal and Their Excellencies the Governors of Bihar and Bengal for the interest shown in our work and the help provided during the course of the investigation. It was a time of abnormal difficulty and discomfort. Our thanks are due also to all those many officials and private persons upon whose assistance and hospitality we were so dependent for the completion of the investigation. Finally we would express our appreciation to all those who replied to questionaires.

CHAPTER II.

DISCUSSION OF SCALES AND ISOSEISMALS.

(J. A. DUNN, J. B. AUDEN AND A. M. N. GHOSH.)

Discussion of scales.

The maps attached to this memoir represent the delineation of the zones of intensity according to the Mercalli modification of the Rossi-Forel scale. On Plate 1 isoseismals VI to X are shown in the regions of Bihar, Nepal and Bengal that were most affected by the earthquake. These were determined by observation in the field and by the assistance of the questionnaires given in Tables 1 and 2. The isoseismals for the whole of India are shown on Plate 2, and were determined by an examination of the replies to the questionnaires which were sent out by the Geological Survey of India and the Meteorological Department. Isoseismals III and II cannot be adequately differentiated.

In the following tables are set out three questionnaires. In Table 1 is shown the standard questionnaire which was in use up till 1935, replies to which determined the drawing of the lower isoseismals in the Bihar-Nepal earthquake. In Table 2 is given the questionnaire which was sent out by the Geological Survey party from Patna through the Government of Bihar and Orissa, at the end of January 1934. This was formulated as a result of the early experience of the earthquake effects in Bihar, and was designed to supplement the work of the party investigating the severely affected area. In Table 3 is shown the new questionnaire which was proposed by the Earthquake Committee of the Geological Survey of India as a substitute for that previously in force. This questionnaire is the one which will be used for future earthquakes.

The Mercalli scale is given in Table 4, together with certain additions and modifications that the field party of the Geological Survey of India have suggested.

The extent of emission of sand from vents and fissures north of the Ganges is sufficient to warrant the inclusion of the factor of sanding as one of the criteria. In North Bihar the emission of

sand is rare outside isoseismal VIII, and reaches its maximum throughout the slump belt within isoseismals IX and X. Factors, such as a capping of hard clay, may sometimes tend to inhibit sanding, even in isoseismal X of the slump belt, but in general the criterion of sanding has been found useful in delineating the isoseismals.

Contrary to what is indicated in the Mercalli scale, it was found in Nepal that landslides occur within isoseismals VIII—X, and not solely in X as is there given. Many of the hill sides in the Himalaya are normally unstable, as is shown by the number of landslides that occur throughout the whole chain quite independently of any seismic disturbance. Solution-brecciation of limestones; weathering of felspar grains in arkosic sandstones, granites and gneisses; well-developed jointing in sandstones and quartzites; bedding planes coincident with the hill slope; angle of slope and undercutting by river erosion; progressive deforestation and exposure of soil cap to sudden downpours of rain; these are all factors which cause non-seismic landslips. It cannot be supposed, therefore, that the landslips arising as a result of the earthquake necessarily indicate the highest degree of intensity. In many instances the shock must have been simply a trigger action that set moving hill slopes which had long previously been unstable.

Construction of the isoseismals.

The delineation of isoseismals is never easy, and, in the case of the Bihar-Nepal earthquake, it proved in places to be difficult. The earthquake affected the three main geological units of India: the Peninsula, the Gangetic alluvium, and the Himalaya. Between these units there are great contrasts in degree of consolidation and in water content of the rocks, with the consequence that the rates of wave propagation, and the amplitude and acceleration of wave motion are very varied. Even within a single unit there is no homogeneity. In addition, there are pronounced differences in the manner of building construction, varying from huts of mud and of mud-plastered bamboo, through *kutcha-pucca* houses to well constructed railway, sugar-factory and government buildings.

During the investigation we were confronted with rapid and often inexplicable changes in intensity throughout even the area

TABLE 1.

Earthquake Report.

Meteorological observatory at——————

1. Date of earthquake . . . .

2. Time of occurrence, if possible exact standard time . .

3. Duration of shock in seconds . . . . .

4. Situation of observer, whether in or out of doors, asleep or awake, sitting or standing, etc.

5. (1) Number of separate shocks, if more than one was felt

   (2) Interval between the shocks . . . . .

6. Were any unusual sounds heard either before, during or after the shock, and what did they resemble ?

7. What was the intensity of the shock, whether strong enough—

   (1) To be felt by persons at rest . . . .

   (2) To make doors, windows, etc., or loose objects rattle, and floors creak.

   (3) To make hanging objects swing ; if so, in what direction.

   (4) To move the observer's seat . . . .

   (5) To throw down loose objects ; if so, in what direction ; give weights and distances if possible.

   (6) To crack the walls of buildings ; give the direction of cracks and alignment of walls.

   (7) To cause greater damage (to be specified) . .

Signature of Observer——————

Date of recording observations——————

TABLE 2.

Earthquake Report.

1. Date of earthquake . . . .
2. Time of occurrence, if possible exact standard time . .
3. Duration of shock in seconds . . . . .
4. (*a*) Number of separate shocks, if more than one was felt
   (*b*) Interval between commencement of separate shocks .
5. Geographical direction of swing of hanging objects . .
6. Direction of movement of ground, floor, etc., during each separate shock.
7. (*a*) Direction of fall of objects such as almirahs, gates, walls, pillars, turrets, etc.
   (*b*) Measurement of such objects . . . . .
8. (*a*) Direction of projection of objects such as bricks from roof copings.
   (*b*) Height from which projected, distance projected and weight of object.
9. Direction of cracks in walls, etc., mentioning geographical alignment of wall.
10. (*a*) Direction of fissures in ground . . . . .
    (*b*) Width of fissures . . . .
11. Phenomena associated with formation of sand and/or water vents.
12. Any unusual phenomena in rivers, large tanks and wells .
13. Type of buildings most affected—concrete, pucca brick, semi-pucca brick, or mud huts; whether heavy or light roof. Type of foundation.
14. Distortion of railway and road alignment . . .

Signed————————————

Address ————————————

TABLE 3.

Earthquake Report.

Place of observation :—

(i) town or village

(ii) tahsil, taluka

(iii) district or state

(iv) nearest railway station.

1. Date of earthquake (day begins and ends at midnight) .

2. Time of occurrence, if possible Indian Standard Time

3. Number of separate shocks, if more than one was felt, and intervals between.

4. Duration of shock or shocks in seconds . . . .

5. Situation of observer, whether in or out of doors, asleep or awake, sitting or standing, etc.

6. Type of building of observer's house, *i.e.*, kutcha, kutcha-pucca, pucca, one or more storeys. When was it built ?

7. Were any unusual sounds heard either before, during or after the shock and what did they resemble ?

8. What was the nature of the movement and did it appear to come from any particular direction, as ascertained from line of swing of hanging lamps, movement of liquids in cups, tubs or tanks ?

9. Was the intensity of the shock strong enough to have the following effects—
   (*a*) To be felt by persons sitting or lying ? . . . .
   (*b*) To be felt by persons in motion ? . . . .
   (*c*) To make doors, windows, etc., or loose objects rattle ?
   (*d*) To make hanging objects swing ? . . . .
   (*e*) To shake trees and shrubs ? . . . . .
   (*f*) To shake the observer's seat or bed ? . . .
   (*g*) To throw down loose objects on tables and shelves such as clocks, bottles, utensils ?
   (*h*) To crack the walls of buildings ? . . . .
   (*i*) To cause greater damage ? (to be specified) . .
   (*j*) To cause other phenomena such as ground fissures, sand and water spouts, slipping of the banks of tanks or rivers ?

Observer. *Superintendent of Observatory.*

Date

TABLE 4.

Mercalli

Isoseismals.	Additional criteria.	Acceleration: in mm. per sec. per sec. McAdie.	Acceleration in Bihar.
I. Instrumental shock, that is, noted by seismic instruments only.	....	10	..
II. Very slight, felt only by a few persons in conditions of perfect quiet, especially on the upper floors of houses, or by many sensitive and nervous persons.	....		..
III. Slight, felt by several persons, but by few relatively to the number of inhabitants in a given place; said by them to have been hardly felt, without causing any alarm, and in general without their recognising it was an earthquake until it was known that others had felt it.	....	25	..
IV. Sensible or moderate, not felt generally, but felt by many persons indoors, though by few on the ground-floor, without causing any alarm, but with shaking of fastenings, crystals, creaking of floors, and slight oscillation of suspended objects.	....	50	..
V. Rather strong, felt generally indoors, but by few outside, with waking of those asleep, with alarm of some persons, rattling of doors, ringing of bells, rather large oscillation of suspended objects, stopping of clocks.	....	100	..

TABLE 4—*contd.*

scale.

Isoseismal.	Additional criteria.	Accelera-tion : in mm. per sec. per sec. McAdie.	Acceleration in Bihar.
VI. Strong, felt by everyone indoors, and by many with alarm and flight into the open air; fall of objects in houses, fall of plaster with some cracks in badly built houses.	....	250	..
VII. Very strong, felt with general alarm and flight from houses, sensible also out-of-doors; ringing of church-bells, fall of chimney pots and tiles; cracks in numerous buildings, but generally slight.	Very rare sand vents .	500	..
VIII. Ruinous, felt with great alarm, partial ruin of some houses, and frequent and considerable cracks in others; without loss of life, or only with a few isolated cases of personal injury.	Moderate degree of sanding. Fissures in alluvial ground. Landslides. Slight mortality.	1,000	1,500 (4·9 ft. per sec. per sec.)
IX. Disastrous, with complete or nearly complete ruin of some houses and serious cracks in many others, so as to render them uninhabitable; a few lives lost in different parts of populous places.	Sanding intense. Extensive fissuring in alluvial ground. Landslides. Heavy mortality.	2,500	2,000 to 3,050 (6·5-10·1 ft. per sec. per sec.)
X. Very disastrous, with ruin of many buildings and great loss of life, cracks in the ground, landslips from mountains, etc.	Sanding intense. Extensive fissuring in alluvial ground. Landslides. Very heavy mortality.	5,000 10,000	3,270 (10·7 ft. per sec. per sec.)

of maximum damage. The question arose as to whether it was necessary to assume an actual diminution in intensity in these lightly affected areas, and hence to split up the whole region into irregularly disposed patches of high isoseismals enclosed within a more general area of low intensity, or whether the shadow areas should be regarded as an indication of apparent and not intrinsic intensity, and a general isoseismal should be drawn to embrace collectively the isolated areas in which damage was of the same high order. Ideally it would have been best in any case to have mapped all the shadow areas, but time did not permit of such detail. We were compelled to regard the areas of low damage as indicating only an apparently low intensity, and to draw the isoseismals in a generalised way, taking notice of the peaks of damage conforming to the various grades of the scale, and ignoring the intervening shadow areas. On the other hand, it seemed impossible to ignore the separation of the high intensity areas in the Katmandu valley, and between Patna and Monghyr, from the main central region by more clearly defined areas of low intensity, so that our map does not include all the areas of intensity IX and X within a single closed isoseismal IX.

An attempt was made by Mr. Williamson (now Sir J. Williamson), Agent of the B. and N. W. Railway, to make a rough isoseismal map from the data which was accessible to him. He assumed the epicentral area to lie 30 miles north of Sitamarhi. Around this he marked a star-shaped area with rays enclosing regions of severe damage pointing to Katmandu (70 miles), Darjeeling (160 miles), Banmankhi (120 miles), Monghyr (120 miles), Sonpur (90 miles) and Chapra Kutcheri (100 miles). This map was evidently based chiefly on the damage occasioned by the various lines of the B. and N. W. Railway. Damage to these lines was divided into severe and less severe, and the rays of the star-shaped area were drawn to include the parts of the severely damaged lines. The country between the railway lines was considered by him to be less severely affected and is shown as inbayments of lower intensity. The value of this map is in the exact information it gives of the damage to railway property. It is of interest also in showing the deception which may result from taking account of information derived almost entirely from arbitrarily selected localities. Fig. 1 is based largely upon Mr. Williamson's map as well as upon our own observations of the damage incurred by the Eastern Bengal Railway.

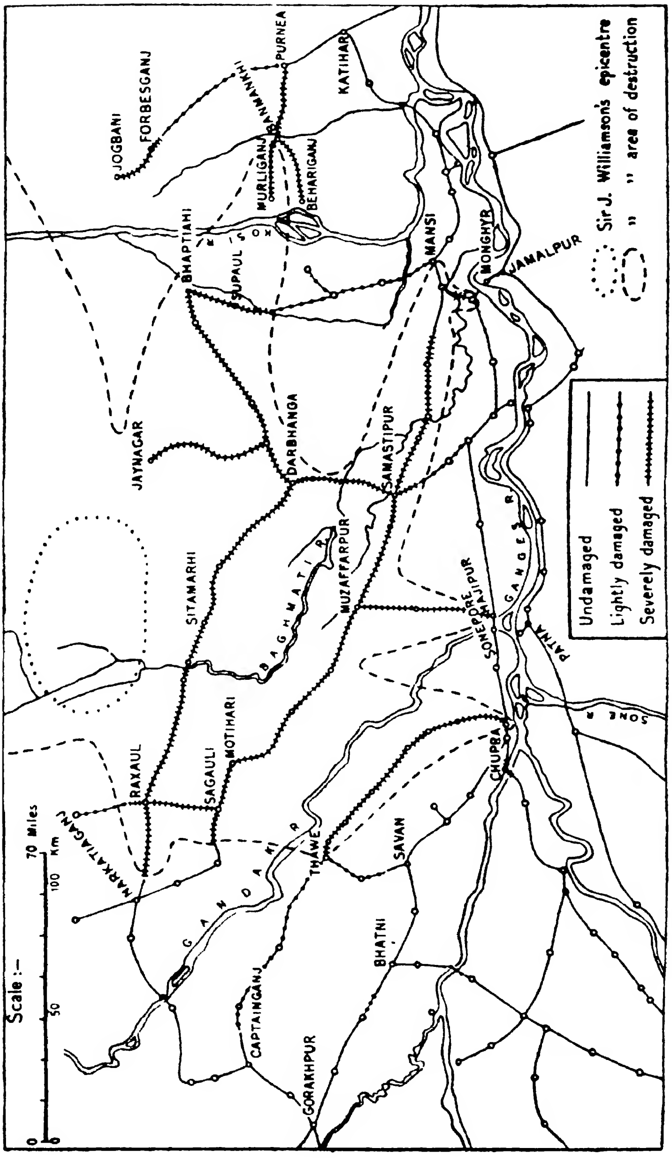

FIG. 1.—Railway lines affected by the Bihar-Nepal earthquake.

Some of the factors tending to control the apparent intensity of the shock may now be summarised :—

(1) Seismographic evidence indicates that the epicentre lies around 26° 18′ : 86° 18′ on the eastern edge of the region covered by isoseismal X. In general, the intensity diminishes with increasing distance away from this region.

(2) The high intensity region of the Nepal valley probably arises from the presence in the valley of unconsolidated alluvium.

(3) The extreme severity experienced at Monghyr is connected with the occurrence of a thin shelf of alluvium abutting against Archaean quartzites.

(4) Damage was great along river banks and in low-lying water-logged lands bordering the rivers. It was less on thick clay beds. There was, nevertheless, a zone of slumping which cuts obliquely across the river tracts and the intervening slightly higher ground, and which we consider indicates the hidden fault disturbance.

(5) Damage was intensified on unstable hill slopes.

(6) Damage in the central region was more by slumping than by collapse. Away from this region slumping did not occur but collapse was prominent. Collapse was most pronounced in *kutcha-pucca* buildings and less in *pucca* buildings or huts built of bamboo with mud plaster.

We have already stated that the scale adopted in determining the isoseismals for the Preliminary Report was that of Mercalli Isoseismal IX was relatively easy to determine over considerable areas, once it was decided to use only the evidence of maximum apparent damage. The central isoseist X must, however, be considered to be more arbitrary since it was difficult to differentiate the slump area into more severely and less severely affected regions.

The scale normally adopted by the Geological Survey of India is the Rossi-Forel scale, which is pitched in such a way that R.-F. X is roughly equivalent to Mercalli IX and X. For a truer comparison to be made with some of the other Indian earthquakes, it would be better to consider the whole of the area within Mercalli isoseismal IX as that in which the earthquake was severely felt. This area is approximately 14,000 square miles or 36,200 square km. in extent.

General description of the isoseismals.

In this section we shall outline briefly the character of damage and other earthquake effects within the several isoseismals. These effects are discussed town by town in much greater detail in Part II, but the object here is to give a summary of the general conditions over the region enclosed by each isoseismal.

Isoseismal X.

A study of the isoseismal lines reveals three tracts where the intensity reached the degree of X. The largest of these, a flattened but regular ellipse, occupies a belt some 20 miles in width striking E. S. E. for some 80 miles from east of Motihari through Sitamarhi to Madhubani. Buildings within this area were destroyed more by slumping than by actual collapse. Another area of isoseismal X, a slightly irregular ellipse, lies south-east of Katmandu and strikes W. S. W.—E. N. E. for about 10 miles, including the town of Bhatgaon. The third is at Monghyr. The total area included within isoseismal X approximates to 1,300 square miles or 3,400 square kilometres. Within the areas enclosed by isoseismal X in the Nepal valley and at Monghyr the majority of the buildings were practically razed to the ground.

Sitamarhi-Madhubani area.— Within the Sitamarhi-Madhubani area a general subsidence of the ground took place, giving rise to widespread fissuring and to destruction of buildings by tilting and breaking up of the foundations. In large sub-divisional towns, such as Sitamarhi and Madhubani, many buildings slumped bodily, or individual walls slumped relatively to adjacent walls. Although the actual collapse of houses, in the sense of tumbling to the ground, was not excessive, not a house of any weight within this area escaped tilting and sinking and few were inhabitable, especially at Sitamarhi. This meant entire ruin and left no alternative but to rebuild the houses. Fissuring of the ground in this belt was severe and emission of sand reached its maximum, covering the floors of houses, streets and drains in towns, and covering the countryside with thick mantles of sand. Wells were choked with sand almost to the brim. Fissures and sand vents threw out sand three to four feet deep, the thickness dying out away from the centres of ejection. Sand and water vents and crater-like depressions lay in profusion in the lowlands. The walls of heavy buildings,

such as the Raja of Darbhanga's palace at Rajnagar, were dissected by gaping cracks a foot or more wide. Over considerable sections in this area roads and causeways subsided; embankments originally six feet high were found at ground level, and borrowpits alongside the roads were often filled with sand. The majority of masonry bridges on the various roads had either collapsed or were severely damaged. Screw pile bridges fared better, although many of them were severely twisted and buckled. As will be seen from Plate 1 the whole of this area lies within the slump belt, which extends from the eastern part of the Saran district as far east as Purnea.

Monghyr.—Monghyr is an old town built both on alluvium and on Archaean rocks. This was the worst affected town in Bihar, and here the devastation was most spectacular as far as the collapse of buildings was concerned. The devastation was greatest in the Chauk section of Monghyr bazar where houses collapsed wholesale and scarcely a building or wall was left standing within an area of 12 acres. The remainder of the bazar was, however, much less affected. As a rule buildings on rock outcrops were damaged less than those on alluvium. The north-west corner of the town within the Fort suffered but slightly. The main damage to *pucca* buildings occurred along the north wall of the Fort, particularly at the eastern end, that is, on the alluvium at the edge of the high ground, where all the buildings were destroyed. The damage done to buildings at Monghyr was entirely due to the severe shaking which the town received; neither fissures nor slumping of the ground were noticeable except near the edge of the river on the north. The general direction of collapse throughout Monghyr was mainly to the east.

Nepal valley.—The area in the Nepal valley enclosed by isoseismal X runs E. N. E.—W. S. W. through Bhatgaon, Harisidhi, Khokna and Bagmati. Bhatgaon showed about a 70 per cent. collapse of houses, while at Harisidhi, Khokna and Bagmati there was total destruction. Destruction in Bhatgaon was not uniform, counts along the streets showing six out of six, seven out of nine, five out of six and two out of five houses destroyed. Temples suffered less, and houses, built of polished brick, neatly and closely fitting, generally escaped. The famous Nyatpola temple, five stories high, was surprisingly undamaged. The Vhairaba temple collapsed. The condition at Harisidhi, Khokna and Bagmati was one of complete ruin.

At the time of visit, one month after the earthquake, bodies were still being recovered from a mass of debris which had obliterated the alignments of the alley-ways. In spite of this destruction of houses, there was, however, little in the condition of the ground to suggest a violent earthquake. Slipping was only seldom found to have occurred even along the edges of the river terraces and there was only one observed occurrence of a sand vent, near Harisidhi. Subsidence of the ground, and tilting and slumping of the houses were entirely absent. The type of damage was similar to that at Monghyr.

Isoseismal IX.

As remarked on page 16, isoseismal IX of the Mercalli scale corresponds approximately to the Rossi-Forel X, a fact which should be borne in mind when comparing the Bihar-Nepal earthquake with other shocks.

The combined areas of very severe intensity equal to IX on the Mercalli scale cover about 14,000 square miles or 36,200 square kilometres in Bihar and Nepal. Isoseismal IX is found in three regions, the largest of which is bounded by an irregular elliptical curve extending 160 miles E. S. E. from west of Motihari to Purnea, and from the Nepal border to the south of Muzaffarpur and Darbhanga. The pronounced embayment of the curve on its eastern side is noteworthy. The next large one is a narrow elongated zone, which extends from Patna to Monghyr, cutting off the northern salients of the Ganges. In the Nepal valley another area within isoseismal IX includes Katmandu and Patan. Buildings within the central isoseismal IX were damaged partly by slumping and partly by actual collapse and tumbling to the ground. The three areas are separated by wide belts of rather lower intensity in which the damage was equivalent to No. VIII on the Mercalli scale.

North Bihar.—The largest area within isoseismal IX lies in North Bihar and along the Terai and southern ranges of Nepal. The presence of towns along the eastern, southern and western borders of this area enabled a fairly accurate demarcation to be made in these directions. To the north, in Nepal, towns are absent (Udaipur Garhi is only a village) and the boundary there is somewhat hypothetical. Moreover, it was only possible to visit a limited number of places in Nepal, and the local officials who were

encountered appeared to know nothing of the condition in neighbouring districts.

The slump belt is completely enclosed by this isoseismal. Within the part of this belt included within isoseismal IX the damage was on the whole similar to, but less intense than that in the more localised region of isoseismal X. Outside the slump belt, in places such as Muzaffarpur and Darbhanga, there was widespread shaking and collapse, but less tilting and subsidence. Prominent fissures and faults in the alluvium were generally confined to the vicinity of such depressions as rivers and lakes. Emission of sand and water was also prominent within parts of isoseismal IX not included within the slump belt, but was more or less independent of slumping.

The phenomenon of slumping is probably, in the first instance, a function of distance from the focal region, but modified by local ground conditions.

Kutcha-pucca buildings suffered more damage than *pucca* buildings or mud huts. Well built masonry structures, especially if of two or more stories, did not, however, escape, as is witnessed by the destruction of the Agricultural Research Institute at Pusa, and the palaces of the Darbhanga Raj at Darbhanga.

A feature of the damage in the region enclosed by this isoseismal and that of No. X, is the number of earthquake shadows present. Between Muzaffarpur and Sitamarhi there are at least two zones along which destruction is small. The damage to buildings in any one town also presents anomalies.

Of nearly 900 miles of line belonging to the Bengal and North-Western railway traversing North Bihar, scarcely one mile of track was undisturbed. Embankments subsided, the track was distorted and every bridge was damaged, many being completely destroyed (see Plates 31, 32, 35, 36).

Patna-Monghyr.—A narrow zone of high intensity, reaching the degree of IX on the Mercalli scale, extends from Patna eastwards to Monghyr, cutting off the northern salients of the Ganges. The important towns affected within this zone are Patna, Barh, Monghyr and Jamalpur. In Patna the worst damage took place along the river front. This is not entirely due to the fact that the oldest structures are located here, as several fine modern buildings were also severely damaged. Similarly, at Barh the effects of the earthquake were more pronounced approaching the river. At

Jamalpur the bazar area and railway quarters near the station were most severely damaged, but the newer buildings towards the outskirts of the town on the east and south sides were scarcely affected.

Nepal valley.—The greater part of the low-lying areas in the Nepal valley is included within isoseismal IX. The towns of Katmandu, Patan, Thimi and Thankot were all severely damaged, showing approximately a 25 per cent. collapse of houses. Thankot lies in a small area of isoseismal IX, which is separated from the main area by a continuation of the Kirtipur ridge. The actual position of isoseismal line IX is determined by the relationship between the soft unconsolidated fluviatile and lacustrine sediments which make up the low-lying portions of the valley, and the older, harder, pre-Tertiary rocks, which form an irregular rim to the valley. The pre-Tertiary rocks consist of granite, gneiss, quartz-schist, quartzite., calcareous quartzite and limestone. Villages situated on outcrops of these rocks escaped severe damage and frequently scarcely suffered at all. This was especially evident in the area between Pashupatinath, Boddhanath, Gokarna and Sundarijal. The ridge of Kirtipur and the hill of Swayambunath also escaped. It was found that damage to property on the recent, loosely-compacted sediments of the valley bears little relationship to the nature of the sediments locally present. Gravels, sands and clays proved equally ineffective in damping the shock.

Fissuring was very rare in the Nepal valley, being noticed only on the parade ground at Katmandu and along the flats bordering the *nala* near Nakhandol. No sand vents were seen within the area enclosed between isoseismals IX and X. The disturbance to the ground was clearly less than that within the Gangetic alluvium of North Bihar and the Nepal terai. This may be explained by the fact that water-logged sands are absent from the Nepal valley, any excess of water in the strata flowing out from the edges of the terraces in the alluvium.

The palaces and houses in the bazar were equally affected by damage. Some of the temples of superior construction, and many houses built of nearly-fitting polished brick, escaped. In the palaces, the wings and upper stories suffered the most.

As in Bihar, one of the chief factors responsible for the loss incurred is the poor quality of the materials employed in construction.

Isoseismal VIII.

Isoseismal No. VIII encloses an area of 31,000 square miles (80,300 square kilometres) in Bihar, Bengal and Nepal. The line was demarcated with fair certainty in British India. In Nepal it was crossed or approached in three places. The form of the line near Katmandu is influenced by local topographical, and presumably geological, conditions. Chainpur and Taplejung indicated an intensity of about VIII, so that the line near these places is definite. The dotted lines to the north are purely hypothetical.

The most important towns situated near the edge of this isoseismal are Bhagalpur, Bihar, Chapra, Bettiah, Darjeeling and Kurseong; other important towns affected within this zone were Dhankuta, Khagaria and Samastipur. Practically every brick-built building bore some stamp of the earthquake. A number of old and weak buildings collapsed. Damage was seen also in the upper stories, wings and porches of newer houses, and in the fall of temple spires and mosque minarets. Many mud houses in the Begu Sarai sub-division, north of Teghra, were razed to the ground. Destruction was particularly prevalent near the western bank of the Gandak in Saran district, which is close to the western end of the slump belt. However, with the exception of two places in Patna district, damage due to slumping and subsidence in this area was practically *nil.*

Fissures and sand vents occurred sporadically within the area enclosed by isoseismal VIII which lies north of the Ganges, but were considerably less in importance than within the higher isoseismals. Few wells in this area were reported to have been choked with sand.

Railway bridges and permanent ways north of the Ganges suffered considerably, but not to the same extent as those within isoseismals X and IX. Two 200 feet girders of the Inchcape bridge on the Gogra, west of Chapra were thrown down; several piers of the Bur Gandak Bridge near Rushera Ghat were fractured and had girders displaced; a pier of the Bur Gandak bridge near Khagaria was sheared and the 100 feet spans of the Bur Gandak bridge near Samastipur had overridden the roller bearings.

A zone of rather high intensity at the S. S. W. corner of the isoseismal stretches for over 50 miles in a W. N. W.—E. S. E. direction from south-west of Arrah to east of Bihar, where many of the buildings were severely fractured. North of this belt, and south

of isoseismal IX, the damage was distinctly less. This belt has been separated from the normal isoseismal VIII by dotted lines, and is designated VIII. Fissures and sand vents were formed at Bikram, south of Hilsa, north of Luckee Sarai and north-east of Sitakund. At Bikram they were accompanied by subsidence of buildings. In general, fissures and sand vents were absent south of the Ganges.

The eastward continuation of isoseismal VIII includes the hill stations of Darjeeling and Kurseong. In Darjeeling several houses totally collapsed. Others were damaged by the crashing of heavy masonry chimneys through roofs and upper floors. Ground fissures were present at several places in Darjeeling, Tindharia and the Nepal hill villages.

Isoseismal VII.

Isoseismal VII has been prepared in the main from the answers to the earthquake questionnaire. The comparatively large area circumscribed is marked by a rapid diminution in apparent intensity as expressed in house damage, and the destructive power of the earthquake becomes visibly less. Within isoseismal VIII, the effects of the earthquake were sufficiently strong to invite general attention, whereas within VII a detailed enquiry had to be made before the violence of the shock could be gauged. In course of his investigations at Gorakhpur one of the authors would not have noticed any damage but for information from local residents; the outward normal appearance of buildings gave no hint that an earthquake had taken place. Nevertheless, several large towns situated on the banks of the Ganges, such as Mirzapur, Benares and Allahabad, evinced a certain amount of major damage of the nature of collapsed houses, fallen chimneys and severe cracking of walls. There were even one or two sand vents at Benares.

The delineation of the southern boundary of this isoseismal is the result of the visit of Dr. Dunn to the Santal Parganas and Gaya and Hazaribagh districts. A zone of increased intensity, running approximately W. N. W.–E. S. E., occurs within this isoseismal, extending from the Santal Parganas, between Jasidih and Dumka, through Gaya, thence continuing towards Allahabad, Mirzapur and Benares, where the damage, although not quite as high as at Gaya, is somewhat higher than the normal for isoseismal VII.

ISOSEISMAL VI.

Except for Chota Nagpur, to the south of the epicentre, and also Calcutta, the greater part of the region covered by isoseismal VI has been estimated from the replies to questionnaires. A very significant feature of this isoseismal is its enormous extension to the west, into Rajputana, over a width of nearly 400 miles.

Some of the features of this zone indicate the high standard of intensity which we have set in judging damage for delineating the isoseismals of this earthquake. Cracks were very common in buildings, not only in those of old or poor construction, but also in new structures of most excellent materials, particularly in such places as Dhanbad and Ranchi. Plaster commonly came off the walls, objects were thoroughly shaken and occasionally small ornaments and bottles fell. One of the authors, enjoying a bath at the time, in Dhanbad, can testify to the violence of the shock there. Most people ran out of doors wherever possible.

This isoseismal includes a number of large towns, such as Agra, Lucknow, Cawnpore, Katni, Ranchi, Dhanbad, Asansol, Burdwan, Dhubri, but the most important is Calcutta which we have included at the southern edge of the area enclosed by it.

Perhaps the first note concerning the earthquake was written by Dr. Coulson, of the Geological Survey, in Calcutta a few minutes after it occurred. He remarked that the shock took place at about 2·40 p. m. Calcutta time, and lasted for about five minutes. Most of those who were in the Geological Survey building rushed out of doors and stood by the lake. He noticed that the lake water was in considerable movement, lapping the northern edge. The shock was sufficient to shake doors of almirahs and papers on his desk. The fans and hanging lights commenced swinging from north to south (maximum double amplitude about 18-22 inches) and were still swinging at 3·00 p. m. Minor cracks were developed in the building, particularly along old fractures.

Cracks were developed in quite a number of buildings in Calcutta, but few were serious. At St. Paul's Cathedral the cracks below the steeple (a very old structure) so weakened the structure that it later became necessary to demolish the steeple and tower and to reconstruct that part of the Cathedral.

Movement in Calcutta appears to have been considerable; an observer at the top of Tower House, the tallest building in Calcutta,

looking down vertically to the pavement below, noted that the top of the building appeared to be describing a kidney-shaped figure with a diameter of 30 inches. On the other hand the then Director of the Geological Survey, sitting in his room at the south end of the second floor, was quite unaware of any earthquake.

Isoseismal V and lower.

All the lower isoseismals were drawn from the information supplied in the replies to questionnaires. The position of isoseismal V was very definite and entailed little discussion as to its delineation; outside of its limits there was a decidedly rapid diminution in the proportion of people by whom the shock was felt. In the Preliminary Report, written in 1934, isoseismals IV, III and II were grouped together, but Mr. A. M. N. Ghosh, whilst abstracting the replies to questionnaires, has since been able to separate IV from III and II. Isoseismals III and II were grouped together as the information supplied in the replies to questionnaires was insufficient and too inconsistent to admit of separating them.

There is difficulty in determining the boundary of the area over which the shock was felt. Thus, a fairly consistent line runs from just south of Bombay to just south of Ongole, south of which almost all the replies to the questionnaire report that no shock was felt (Satara, Sholapur, Kurnool, Nellore). Yet, the shock was felt very slightly by two people near Madras and by two others at Dharwar. We have drawn isoseismal line II to separate the area over which the shock was felt in general from that over which the great majority of people failed to notice a shock. The estimated area of 1,900,000 square miles, over which the shock was felt in general, is that enclosed by isoseismal II.

There are three unusual features to which attention must be drawn. North-west of Gauhati there is an area in the Brahmaputra valley in which the intensity was IV, definitely lower than that of country on all sides. Around Cuttack on the Mahanadi delta there is a small area, isolated in isoseismal IV, in which the intensity was severe even for V and approached the severity of VI. Similarly, on the Godavari-Kistna delta, there is a local area of intensity IV isolated within isoseismal II-III.

Other shocks.

A shock was reported as having been felt at about the same time as the main earthquake in the south-western coastal region of Peninsular India, including South Kanara, Coorg and Travancore. As a somewhat similar sympathetic shock occurred at Madura in South India about six minutes after the Srimangal (Bengal) earthquake of 8th July 1918, some credence was at first given to the reports from South India following the shock of the 15th January. Closer enquiry throws considerable doubt on the reports. It was only after knowledge of the shock in the north became public that a few people in Cochin remarked that they had felt a momentary giddiness at 2·15 p.m. on the 15th of January. The impression was also heightened by the fact that there was an unusual swell on at the time outside the harbour. The Harbour Engineer-in-chief reported that certain buildings on reclaimed land had subsided $\frac{3}{4}$-inch as a result of the earthquake, but as the measurements were not taken until some time later it is doubtful whether they were related to any presumed shock. There is, however, the possibility that the recent sediments, along this part of the west coast, gave rise to a local increase in intensity in a similar manner to the local increases at the mouths of the Mahanadi and Godavari rivers.

Reports submitted more than two months later from South India described a shock occurring in the early morning between 2·30 and 2·40 on a date variously reported as from the 11th to 16th, but according to the majority on the 12th. This shock certainly cannot be described as a "sympathetic shock" to the Bihar earthquake. Most people were asleep and the shock was reported as lasting from one to 30 seconds.

A shock was reported from near Moulmein in Amherst, Burma, at a distance of 250 miles south-east of the limits at which the main earthquake was felt. The well-populated area around Rangoon and Pegu, in which no shock was felt, intervened between Moulmein and the limit of the main earthquake, and the evidence of the local shock is doubtful.

CHAPTER III.

EARTHQUAKE EFFECTS.

(J. A. DUNN, J. B. AUDEN AND A. M. N. GHOSH.)

Sounds.

Much has been written on earthquake sounds and their variation from place to place; they are always close to the lower limit of audition. Any vibrating body will give out sound waves providing the frequency is within the range of audition, and the pitch will vary with the frequency. Practically all observers agree that the Bihar earthquake was preceded and accompanied by sound, variously described as comparable with the noise of "several aeroplanes", "a heavy motor lorry", "an approaching goods train", "a passing motor car", or "a train passing through a tunnel". In the central region several observers recorded that the sound appeared to emanate from the ground beneath their feet. One of the authors, who was having a bath in a bungalow situated within isoseismal VI, thought at first that the noise was due to a sudden sharp windstorm. The sound was loudest within isoseismals VIII to X, and masked the noise caused by the collapse of buildings, the rattling of doors, windows, furniture, etc. The sound was recorded from places as far away as isoseismal V. During some of the aftershocks similar sounds were heard locally.

Difficulty has sometimes been expressed in explanation of the fact that shocks are often said to be heard before they are felt, as seismic waves are faster than sound waves. However the sounds emitted are independent of the *speed* of the seismic waves, but are indirectly dependent upon the *frequency* of those waves. The *frequency* of a vibration determines whether or not it is audible; the *amplitude* of a seismic wave determines whether or not it is felt. A low amplitude wave may not be felt, but its frequency may be such that the sound wave emitted may be audible. Still, the relation between the seismic vibrations and the pitch of the sound waves cannot be a simple one. During the transmission of seismic waves, rock particles are moving rapidly against each other and the secondary vibrations so set up may give rise to sound waves.

Sounds have also been recorded as arriving several minutes subsequent to earthquake shocks. These are usually of the nature of heavy reverberations and come from a definite direction, usually that of the epicentre. Hayes (1929) points out that they are atmospheric disturbances produced by crustal movement at the epicentre and travel with the speed of sound but take a long path through the upper atmosphere. Sounds of this nature were not heard after the Bihar shock ; even if they had occurred it is doubtful whether they would have been noticed in the excitement following the shock.

It is interesting to note that in the area north of the Ganges there was a general consensus of opinion that the sound passed from a north-westerly to a south-easterly direction. It is now difficult to judge whether or not this consistently described direction was a psychological effect arising from the early acceptance of the epicentre as being in the Himalayan foothills. It is difficult to reconcile the direction with the speed of transference of shear waves, and, so far as we can judge, the sound was heard more or less simultaneously over the whole area and cannot accordingly have originated from a point. One suspects that the consistently reported direction of movement of the sound may also be psychologically connected roughly with the felt direction of movement.

Ground movements.

Ground movements during the shock naturally reached their maximum within the central tract. It has not been possible to obtain any consistent description of these movements, but the brief emotional minutes of an earthquake crisis are scarcely conducive to sustained exact observation. Certain facts do stand out, however, the principal amongst which being that both horizontal and vertical movements were experienced and the movements at any one place varied at different stages during the progress of the shock : for a time the main movement may have been east-west, then it changed to north-south, and again to vertical ; many people felt also a circular movement both clockwise and anti-clockwise. Some observers recorded a distinct pause or diminution in intensity between the change in direction of the movement ; indeed, the great majority of observers remarked that the main damage was done immediately after one such lull in intensity. Occasional

observers remarked that the shock reached its full intensity almost at the commencement and continued without pause until the end, but easily the greatest number of people noted that the maximum intensity was not reached for some time.

In the central tract few people could stand unsupported, and even in towns as far distant as Gaya and Dumka many had to sit on the ground. One of the keenest observers, a police official who was sitting calmly on the ground outside his bungalow at Motihari, recorded three distinct thuds directed upwards.

On the whole the majority of observers appear to have noted an approximately east-west trend for the principal destructive movements, except in the epicentral region, and this alignment is consistent with the general (although by no means invariable) direction of the fall of such objects as were free to collapse in any direction. This east-west movement was noticed by the swing of objects even as far south as Ganjam district, south of the Mahanadi river, in Madras Presidency. Within isoseismal X the fall of objects was consistently north and south.

Large surface undulations were actually seen by many people, and their occurrence in an earthquake of this magnitude must be accepted as authentic. They were seen as far away as Asansol, in isoseismal VI some 250 miles from the epicentral tract, by a group of colliery managers who described them as moving over the alluvium from west to east, perhaps 12 feet from crest to crest and 6 inches in height from trough to crest. An observer at Muzaffarpur, close to the epicentral tract, considered the crest to crest distance to be 5 feet and the amplitude about 6 inches. Others have stated that buildings seemed to be tilted backwards and forwards on the crests of much larger undulations. The west compound wall of the Belsund Sugar Factory at Riga, aligned north-south, remained in wave form with two crests and a trough; the crest distance was 240 feet and the total vertical displacement one foot. A north-south watercourse at the Sugar Cane Research Station at Mushari also remained in the form of waves whose crest to crest distance varied, one measuring 240 feet. These two observations were taken in localities where ground subsidence was considerable, and it is possible that, although the waves were noticed only along structures with a north-south alignment in localities where the fall of objects independently suggested north-south movements, they should be regarded as due to subsidence

and not as examples of "frozen undulations". The concrete floor of the civil court at Motihari was broken up by close fractures in just such a manner as might be expected by the passing of surface undulations.

Notwithstanding that many seismologists are disinclined to believe in the existence of such undulations, the authors of this memoir have no difficulty in accepting them as an established accompaniment of earthquakes of this magnitude, even although the dimensions given by observers may be exaggerated. These slow moving undulations must not be confused with the waves of high acceleration which cause the overturning of pillars, etc. The undulations do not, of course, radiate from the epicentral region, but are generated locally, apparently usually in alluvium, as a surface effect of the earthquake waves proper; they travel slowly, perhaps 10 to 12 miles per hour, and individual undulations rapidly die out.

Several observers have described the manner in which trees and telegraph poles were shaken; many of the latter came down, but surprisingly few trees were uprooted. Palm trees, being supple, whipped about like canes.

Collapse of buildings.

The worst effect of an earthquake, apart from loss of life, is the collapse of buildings. There is, curiously enough, little information on the manner in which such collapse took place. In some instances this collapse appears to have been piecemeal, but in many cases the whole building crashed instantaneously. One resident of Monghyr was sitting outside a bungalow and watched the cracks form in the wall "just like forked lightning", the cracks opened and closed during the remainder of the movement as if opposite corners of the building were being alternately raised and lowered—the passing of surface undulations just described would have some such effect. Cracks which developed in concrete floors also appear to have opened and closed in the same way. Frequently the cracks in both walls and floors remained gaping.

As a general rule the oldest buildings were the most severely damaged, and usually collapsed in the central area. The oldest buildings in North Bihar were constructed with mud mortar and there was little to bind the bricks together. Still, quite a considerable percentage of the better type of buildings did not escape

damage, many being destroyed. One of the finest buildings in this part of Bihar was the Pusa Agricultural Institute, a large well-built structure of stone and brick; this was traversed from end to end and from roof to foundation by great gaping fractures which rendered the building completely useless.

Buildings were destroyed in either of two ways: by actual shaking down under the action of earthquake waves; by subsidence and spreading or tilting of the foundation. Collapse due to actual shaking was for the most part amongst older and badly constructed buildings. Destruction by subsidence of the foundations, so typical of the "slump belt", affected every type of heavy structure, including those built of the best material.

Monuments were overturned or rotated. Brick arched bridges collapsed, steel girder bridges were destroyed by the piers either overturning or the girders falling. Pile bridges moved irregularly up and down, although most piles seemed to work upwards as the result of the shock; some even moved laterally downstream; in other cases the piles were bent over at right angles as a result of being pushed from either bank. The advantage of screw-pile bridges is that although they may be contorted they are frequently negotiable by traffic after an earthquake.

Damage to railway.

The greater part of the railway system in North Bihar was severely damaged. Some extracts from a report by Mr. J. Williamson, Agent to the Bengal and North-Western Railway, give a clear view of this damage. Fig. 1 shows the lines affected.

"Of the 2,100 miles comprising the Bengal and North Western and Tirhut System, it may be said that on 900 miles traversing North Bihar and the eastern United Provinces hardly a mile of track was undisturbed; embankments settled and even disappeared entirely, the rails remaining suspended, elsewhere they were raised or shifted many feet laterally. The permanent way, even where least distorted, may be likened to a construction line on a new high bank which has passed through a heavy monsoon without attention. So severe is the distortion in places that a trolly could not be safely taken round kinks. Not a bridge remains undamaged from minor cracks in arches, wing walls and abutments, displaced piers and girders, to complete destruction. Training works and guide-banks of large bridges have been cracked and shaken......

"Deeply founded piers and wells of large bridges have been moved many inches either longitudinally to the bridge or laterally."

Fissures.

North of the Ganges the formation of fissures in the ground was very widespread over certain zones. South of the river, such fissures occurred at only three isolated localities.

The fissures were found generally to follow pronounced surface features, such as river banks, lakes, tanks, ditches, road and railway embankments, when these were present. Commonly there were formed concentric circular fissures around heavy buildings. In flat country, devoid of features, the fissures rarely showed any constancy in direction; more generally they occurred as an irregular network.

Sometimes the fissures were arranged as a series of step faults, others resembled trough faults where the ground sank between two parallel fissures. In some the walls of the fissures were closed, in others they were wide apart but infilled with sand and frequently this sand was not up to ground level. The maximum width of any such fissures was about 27 feet, but the majority were less than 12 inches. The length of the fissures varied greatly; one at Pusa was 700 yards in length; more usually they were lessthan 100 yards. There is no reliable information as to the depth of individual fissures. It is doubtful if any extended as open fissures for more than 40 to 50 feet in depth for a period of more than a few seconds, as they were almost immediately filled with sand. Although it is unlikely that individual fissures extended to any considerable depth, it is quite probable that throughout the whole depth of this alluvium a series of dislocations or faults took place as a result of unequal movement of the unconsolidated beds.

Emission of sand and water.

Sand and water were copiously discharged from many fissures, and also from individual vents, and they provided one of the most remarkable features of the earthquake. Such a phenomenon is, of course, common enough in earthquakes over alluvial country, but it may be doubted if any earthquakes in historical times, except those of New Madrid (U. S. A.) in 1811 and 1812, have equalled that of Bihar in the extent of this phenomenon.

It is well to point out that an exaggerated impression of the degree of sanding is obtained by casual eye inspection. Sand vents in a field are more conspicuous than the parts of a field bare

of sand and deceive the eye as to their true areal importance. Actual measurements carried out in two fields which appeared considerably affected by sand, in a region of the Nepal terai near Koilpur (26° 41′ : 86° 17′), gave the following results :—

Field 40 yards square	16 vents.
Field 120 by 90 yards	34 vents.

Taking the average radius of a sand vent and cone in that region to be 2 feet, these fields show respectively 1·4 per cent. and 0·4 per cent. sanding.

Sanding reached its maximum within and close to the "slump belt" which has an area of 4,700 square miles (12,200 square kilometres), but scattered affected areas were found within a region of 18,000 square miles (46,600 square kilometres) forming part of isoseismal VIII and higher isoseismals. The extent of this sanding was popularly much exaggerated during the first few weeks following the catastrophe. Mr. W. D. Brett (1935, pp. 36-37) supplies figures of the sanded area. Within an area of 4,137 square miles only 15 per cent. or 615 square miles was found to be affected. Of this, 7 per cent. contained deposits of sand less than 6 inches deep, 52 per cent. was below one foot, 37 per cent. or 227 square miles contained sand over one foot deep, and 4 per cent. or 24 square miles had deposits of over 2 feet deep. The strong April-May winds carried off and distributed much of the sand and the succeeding monsoon rains continued this work, so that only a very small fraction of the sanded area was permanently affected, and much even of this land proved to have been made actually more fertile. The early view of the Geological Survey that the actual damage due to sanding would be almost negligible has been justified.

It seems to have been a general experience that the uprise of sand and water took place towards the end of the main shock, or after the main shock had subsided, sometimes as much as several minutes later. One observer at Sagauli noticed that it began at 14·20 hours and continued for about 3 hours. Mr. A. Macdonald of the Ryam Sugar Company, Darbhanga, stated that fully six or seven minutes elapsed before ejection of water and sand commenced. Wells continued overflowing there for one and a half hour. Similar delay in the emission of sand and water was noted in the Assam earthquake and quoted by R. D. Oldham (1899, pp. 25-26).

Occasional observers have stated that the water which spouted upwards in the form of geysers reached a height of 30 feet, but it is difficult to credit this figure. The majority of reliable observers give the maximum as 6 to 8 feet, the height gradually diminishing. Most fountains were much less than this maximum and a large amount of water merely flowed gently from fissures. One of the most vivid and accurate accounts of the phenomenon was from the pen of Mr. H. C. Gordon, General Manager of the Sursand Raj. He wrote '............As the rocking ceased........water spouts, hundreds of them throwing up water and sand, were to be observed on the whole face of the country, the sand forming miniature volcanoes, whilst the water spouted out of the craters, some of the spouts were quite 5 feet high. In a few minutes—as far as the eye could see—was vast expanse of sand and water, water and sand. The road spouted water, and wide openings were to be seen across it ahead of me, then under me, and my car sank, while the water and sand bubbled and spat, and sucked, till my axles were covered. "Abandon ship" was quickly obeyed, and my man and I stepped into knee deep hot water and sand and made for shore. It was a surprisingly cold afternoon and to step into such temperature was surprising '.

Lines of sand vents, like the fissures, were found generally to follow pronounced surface features such as river banks, lakes, tanks, ditches, road and railway embankments and, along the "slump belt", sand came up in quantity around the plinths of sunken buildings. It even came up through the floors of houses and factories; about 3,000 cubic feet (85 cubic meters) came up through one portion of the factory floor at Barachakia. Sand flowed into most of the wells and in many cases overflowed from their tops, so that hundreds of wells were found to be completely infilled with sand after the earthquake.

In places the surface was riddled with sand vents, sometimes so completely that small areas, perhaps up to an acre or so in extent, might be compared with boiling porridge. Although the vents sometimes followed certain directions they were generally clustered together haphazardly over the area. Two types of vents were observed. as follows :—

The first type simulated miniature volcanic craters, having a low conical ring-shaped mound with a shallow depression in the centre. The diameter of such vents and cones of extruded sand varied from a few inches up to 20 feet. These vents were generally confined to low marshy ground, old river beds, borrowpits on either side of roads, causeways and railway embankments. In a few instances they were found at the bottom of large fissures.

The second type of sand vent was in the form of a crater-like hollow, with the inner walls sloping towards the centre of the large depression. Much sand and water were discharged from vents of this type. The two diameters of such an elliptical blow-hole, at Muzaffarpur, were found to measure 25 feet and 10 feet. Another at Rajnagar was even larger.

As might be expected the sand was frequently sorted as it flowed from the vents, the coarser material being deposited close by and the finer material further away from the exit. In addition the sand was not uniform either in general texture or in composition throughout the area. This is in accordance with the heterogeneous nature of the alluvial strata from which it was derived. The texture varied from very fine silt to coarse sand. The colour when wet was generally dark ash grey to grey, but became paler as the sand dried. The darker sands owed their colour to finely disseminated particles of carbonaceous matter and to flakes of biotite. North and east of Muzaffarpur a copper coloured mica was prevalent in the sand. In Saran district a rusty yellow sand was common. The absence of clay was noticeable, but to be expected, for in a series of beds of loose sand and clay the former is the more likely to be washed out with the upward rush of water.

In a few places, such as at Purnea and Rajaputty, spindle-shaped lumps of semi-compacted mud and silt were ejected. These were sometimes polished and striated as a result of movement through sand on their upward journey. The largest of such lumps which has come to our notice was one foot in length and five and three-quarter inches in width. At Chakia in Champaran, pieces of wood were ejected.

The sand is unlikely to have come from any great depth, and is not necessarily dependent upon the depth from which the water was propelled. The type of sand and silt emitted often did not differ from that found along present river beds. Mr. Kemp of Pipra, Champaran, states that the sand, locally emitted, is similar to that found between about the 40 and 50 feet levels in the deeper wells. Dr. K. S. Caldwell, of the Science College, Patna, suggests a depth of about 20 feet for the sand in the Muzaffarpur district. Water-bearing sands are common at about this depth below ground level and it is very probably this sand, down to which the wells penetrated, that was forced up to fill them. From a well at Sagauli Sugar Factory three different types of sand emerged, presumably

from three different strata at varying but shallow depths below the well. The casings of two tube wells at Sagauli were both sheared off at 53 feet below ground level, making it impossible to sink rods after the earthquake. Evidently there was differential movement of the strata, and it is possible that this was accompanied by concomitant loss of sand from this level.

The universality of the sand in some places, and the closeness of the vents, suggest no great depth for its origin, since the greater the depth of the channels leading up to the vents the more localised and separated would they probably be. Probably much of the sand in fissures came from beds immediately adjacent to the walls of the fissures.

The topmost water-bearing sand is the horizon that would be most under the influence of the larger amplitude and range of vibration exhibited by earthquake waves acting on the free surface of the alluvium, and hence would be the most likely to escape through fissures and vents. This does not prove, however, that all the sand or water was of shallow origin. It has just been mentioned that three different sands came out of one well at Sagauli. Further, the lumps of clay which came up with the sand at Purnea and other places, are so well rounded that some considerable distance of transport through channels is indicated. Purnea lies on a bed of sand some 80 feet thick, and the clay must have come from some depth greater than this. Water from the deepest affected strata at any one place will carry with it sand from the various overlying water-bearing sands through which it is forced.

It may be pointed out that in sinking *mota* or cavity wells in alluvial ground, water-bearing sands, when first encountered, are often forced up from below in sufficient quantities to fill the well (Lacey, 1926, p. 139). Such *mota* wells require an impermeable stratum of clay above the water-bearing sand. Under normal conditions, therefore, in alluvial country, there may often be a considerable head of pressure to the water in alluvial sands. An earthquake causes the fissuring of the overlying beds and the compression of the water-bearing sands, which may in places have already been under hydrostatic pressure.

Dr. Coggin Brown, in a letter to *Nature* (1934, p. 295), states, following Oldham, that the requisite condition for the emission of sand and water is a bed of impermeable clay. The inertia of this is believed to cause a compression of the watery sub-stratum and

the expulsion of the water and sand through cracks formed simultaneously above. This does not seem a complete explanation, since sand vents were noticed in Bihar in regions where clay is absent, particularly, for example, in Purnea district. Often, indeed, a thick bed of clay seemed to form an impermeable cap to the sand, preventing its emission, probably because it was tenacious enough not to fissure and afford avenues of escape.

The fact that sand and water frequently came up after the shock had subsided suggests that the inertia of the overlying stratum is not the main cause of the compression, since differences in inertia would cease to be of importance once the ground movements caused by the shock had ceased. It is possible that water, already under hydrostatic pressure under natural conditions, rose upwards as a result of the breaching of the overlying strata, and continued to flow until the pressure was relieved.

The shallow depth of most of the sand is suggested by the arguments given above. The water, on the other hand, probably came both from the higher water-bearing sands and from lower down. Compression caused by earthquake waves was probably responsible for the relatively rapid emission of sand and water from higher horizons, while the water which continued to flow for some time afterwards may have come from lower depths where long-standing hydrostatic pressure took some time to be relieved.

The greatest depth from which the water was derived is not, of course, known. The fact that the water was frequently reported to have been hot is some indication that it may have come from a fair depth. In the field we discounted at once most stories regarding the temperature of the water, as being an attempt to attribute unique properties to what was thought to be a unique phenomenon. Thus, at Mushari the water was said to be so hot that it withered the local cane. Mr. K. L. Khanna, Sugar Cane Research Specialist, who was at Mushari at the time of the earthquake, stated that the temperature of the water was in reality about 21°C (70°F). It was more difficult, however, to discount the evidence of reliable people who stated that in places the water was hot. Mr. Dobson, of Belsund, was positive that the temperature of the water coming up in his compound was that of a hot bath, say 43°C (110°F), a figure which, notwithstanding its source, must be accepted with reservation as probably exaggerated.

It is of interest to compare the Bihar-Nepal earthquake with the New Madrid earthquake of 1811 and 1812 (Fuller, 1912). New Madrid lies in the Mississippi valley at Lat. 36° 35′N: Long. 89° 32′W. The river meanders over an alluvial plain which is 60 miles in width, and is flanked on the north-west side by an upland of old Palæozoic rocks and on the south-east side by a young Tertiary plateau. All the phenomena so noticeable in the Bihar-Nepal earthquake occurred also along the Mississippi valley. Clear signs of sanding are still preserved over an area of 1,400 square miles along the alluvial plain west of the Mississippi but, from historical records, it is apparent that a much more extensive area was formerly covered by sand. Whole districts in the neighbourhood of New Madrid were so affected as to be rendered temporarily uninhabitable. The sand occurred in the form of *sand blows*, corresponding to the sand vents of our account, *sand sloughs*, or linear depressions, and *sand scatters* or thin surface coverings of sand.

Slump Belt.

Along a belt of country in North Bihar, enclosed by isoseismal IX, and including the epicentral tract bounded by isoseismal X, there is found to be an intensification of those effects of earthquakes generally manifest in alluvial ground.

This belt was termed the *slump belt* by Dr. Dunn and was meant to indicate the area in which tilting of houses and subsidence of ground were more marked. It encloses an area of 4,700 square miles or 12,200 square kilometres in Bihar. It extends for about 190 miles in a W. N. W.—E. S. E. direction, enclosing wide areas in the Champaran district on the west through Muzaffarpur and Darbhanga district, to as far as Purnea on the east, where it narrows down considerably. On the north it includes, by inference, portions of the Nepal terai.

The chief criterion adopted in the demarcation of this belt was the behaviour of buildings and other structures. These tilted and slumped bodily into the alluvium, but seldom tumbled brick from brick. Sinking was often differential, in proportion to the relative pressures of the parts of the buildings per unit areas.

Subsidence of road causeways and railway embankments was marked, in some cases embankments originally 6 feet high sank

down level with the surrounding country. Tanks, lakes, borrow pits and other depressions became noticeably shallower as a result of uplift of their bottoms—the tendency on the whole was for elevations and depressions to approach a common level. Fissuring and emission of sand and water reached their maximum development along this belt. The effects of slumping were on the whole more marked along lowlands, marshes and near the edges of rivers, lakes and tanks, but were not confined to such localities.

The damage to buildings along this belt is in contrast to that of the area between Muzaffarpur and Darbhanga, where houses were razed to the ground. The fact that both these belts stretch so far in an E. S. E.—W. N. W. direction, crossing rivers and intervening higher land, suggests that their distribution is not primarily associated with the height of the ground water level, for it is improbable that the water table is a uniform height below surface both near the rivers and along the intervening higher land. The explanation of the difference in the type of damage between these two belts is probably to be sought in their disposition relative to the focal region of propagation of the earthquake. The epicentral tract and the slump belt, lying vertically above the focal region, received vertical shocks rather than oblique. Muzaffarpur and Darbhanga, on the other hand, being further removed from the focal region, received an oblique shock, and suffered less slumping but greater shattering.

Mention was made in the preceding section of the extrusion of sand as a result of the New Madrid earthquakes. These earthquakes are of interest also in affording indisputable evidence of vertical movements. Areas of *sunk lands* are still preserved along the alluvial deposits west of the Mississippi valley, over a total extent of about 1,000 square miles. The maximm depression was about 20 feet. Extensive river swamps and lakes developed, and forests were flooded with the result that trees were drowned and stand now, over 100 years after the shock, as dead stumps above water level. The land was locally warped upwards between the sunk lands, both depressions and elevations being attributed by Myron Fuller to the same cause. He states (1912, p. 74):—

"The sunk lands may be divided for convenience into local and general areas. The former, commonly known as sloughs, are nearly always associated with extrusion of sand and may have resulted from undermining incident on the ejection of the quicksand beneath the upper alluvial beds or from the contraction of this

sand caused by its agitation and readjustment by the earthquake vibrations and the loss of its water. The more extensive sunk lands, however, especially when taken collectively, seem to require a more potent cause, there being far too little extruded matter to account for the depressions. This cause is presumably allied to those producing doming.... In brief, the sunk lands probably resulted from a warping and lateral movement incident to a subsidence in the floor of the basin, approximately along the line of the faulting that gave rise to the earthquake."

Changes of level in North Bihar.

Prior to the earthquake evidence had accumulated which suggested that a secular rise had been taking place in parts of Bengal and in North Bihar relative to Calcutta of as much as 0·50 foot per year. A map showing contours of this inferred secular rise was published by Dr. de Graaff Hunter in *Nature* (1934, p. 236). It had long been known that an area of underload occurs in North Bengal and North Bihar, and Dr. Hunter suggested that the land had been rising over the region of underload, the rate of rise increasing as the centre of the region of underload was approached. He also considered that the earthquake had caused a further and sudden rise of land. Both the postulated secular rise and the assumed rise as a consequence of the earthquake were thought to represent a tendency of the crust to reach isostatic equilibrium.

Dr. Hunter's note in *Nature* was published on February 17th, 1934, and was evidently written immediately after the earthquake, before many details were available. In actuality, the land has sunk rather than risen, and Major Bomford, R. E., has been led, as a result of a full examination of the levelling records, to abandon the hypothesis of a secular rise of the alluvium. There remains now a series of level differences which is inexplicable in view of the high precision of the levelling operations.

Shortly after the earthquake, the Survey of India undertook the relevelling of two lines in North Bihar:—Bagaha-Motihari-Muzaffarpur-Darbhanga-Purnea, and Bagaha-Raxual-Sitamarhi-Darbhanga. The results of these surveys are published in the *Geodetic Reports* for 1934 (p. 24), 1935 (p. 11) and 1936 (p. 93). It was assumed that the level of Bagaha was unaffected by the earthquake, the differences in level elsewhere being deduced from this unchanged level. This assumption is certainly reasonable. The fading in intensity of the shock from Bettiah to Bagaha is very rapid; more rapid probably than along any other section across the isoseismals,

Bagaha, though only 32 miles from Bettiah and 93 miles from Sitamarhi, comes within isoseismal VI, and is less damaged than Allahabad, which is in isoseismal VII and is 235 miles from Sitamarhi. The completion in 1936 of a line from Bagaha, through Benares, Allahabad, Cawnpore and Jhansi to Sironj in Central India indicates that this assumption is correct and that for the 70 years previous to 1936 the level of Bagaha has remained unchanged.

An examination in 1934 of the changes in level resulting from the earthquake led us in our Preliminary Report to mark two contours on one of our isoseismal maps, which were designated 'Approximate lines of equal apparent bench mark subsidence determined by re-levelling operations of the Survey of India'. (Auden and Ghosh, 1934, p. 204 and Plate 20.) These contours have now been deleted, because a final examination of the levelling records by Major Bomford indicates the uncertainties which are present in their interpretation. In the Geodetic Report for 1934, p. 25, it is stated :—

'The changes in the old lines are shown in Table 4. The revised figures there given are based on Bagaha, but no other old bench marks are accepted as unchanged. The circuit Bagaha-Motihari-Darbhanga-Sitamarhi-Bagaha had a closing error of +0·696 feet, which has been adjusted. The table shows a sinkage of 1½ feet at Purnea, which so far as the accuracy of the levelling goes should not be error, but which may be due to the earthquake or to a slow rise at Bagaha during the 60 years since the old line was levelled. Elsewhere bench marks show sinkages of up to 4½ feet, and it is noteworthy that there are only four cases of elevation, of which the largest is 0·029 feet. The largest sinkages occurred on structures which had presumably sunk into the ground, and the embedded bench marks generally show smaller changes, although one case of 2·7 feet occurs. Although they are never actually in contact with heavy structures, embedded bench marks are generally in towns, which are areas of accumulation and so liable to local sinkage if underlaid by running sand. Consequently even the embedded bench marks do not provide positive evidence that the country as a whole has sunk, although it seems very possible that it has.'

These results are unsatisfactory because of the uncertainty involved in estimating whether or not the bench marks had slumped into the ground. It should be remarked, however, that level differences of up to 4·3 feet were recorded in the neighbourhood of Darbhanga, a place which lies outside our slump belt and on a bed of clay nearly 80 feet in thickness.

In later Geodetic Reports, the sinkage is considered to be less, for Purnea is regarded as having dropped by only 0·50 foot, and the bench marks between Purnea and Darbhanga by about one foot.

Major Bomford concludes that there is no general tendency of level changes of any significance, and considers that, in view of the closing error of 1½ feet between Darbhanga and Dinajpur, the apparent sinking at Purnea may not be real (1937, p. 94). This conclusion does not vitiate the reality of the slump belt; indeed, the slumping of some of the bench marks is a further indication of the generality of slumping phenomena between Motihari and Purnea. In so far, however, as many of the bench marks which show a drop of level were not considered by the surveyors actually to have sunk into the ground, it seems definite that between Bagaha and Purnea there has been a real, if slight, depression of the land surface, a depression which overlaps but does not coincide exactly with the area demarcated as the Slump Belt. The land has nowhere been elevated more than a fraction of an inch, an amount far smaller than the closing errors of the surveys. It is precisely in those places, such as between Bagaha and Bettiah and at Darbhanga, where slumping was not observed during the geological survey, but where bench marks have sunk, that the evidence for a general slight depression of the land surface may be considered to be strongest.

Effects on rivers.

Mr. Mansfield, Collector of Bhagalpur, who was on tour close to the bank of the Balan river, a south flowing stream on the border of Darbhanga and Bhagalpur districts, during the earthquake, quotes evidence in his report that immediately prior to the shock the river suddenly became dry across its whole width for a short time. This locality was along the line of the epicentre and the evidence, which is reliable, suggests that there was a temporary uplift of the river bed at the commencement of the shock, followed by subsidence back to normal during the shock.

Sir J. Williamson, Agent of the Bengal and North-Western Railway remarks :—

'River banks were further lashed by huge waves; a planter who happened to be standing on the banks of the Bur Gandak at Muzaffarpur says that the river was agitated into waves rising to the top of the banks some 15 feet in height. The agitation of the Gogra at the Inchcape Bridge and Turtipar as described by our railway men was such that the whole river washed from side to side to a great height; this is corroborated by the rutted and broken down sand banks and diara lands'.

He gives also the account of an eye witness :—

'The scene on the river was frightful. Opposite where I stood, there had been an island of sand in the middle of the stream, with a narrow passage of water on the near side and a broader stream on which steamers plied on the far side. The island has become joined to the mainland. On what has been the broad passage, several boats and a river steamer were stranded. Their occupants rocked to and fro as the sand beneath them vibrated. On what had been the narrow passage a number of bathers were left half sucked into the sand by the force of the receding water. They struggled to get free and escape. For the space of several minutes (I estimate that the shock lasted for five minutes) the river bed remained dry. As suddenly as it had vanished before my eyes, the Ganges appeared again, but this time it spouted up from the sand with considerable force. Great cracks and fissures, some as long as fifty feet and several feet wide, appeared at irregular distances and from them columns of water shot up to the height of a man with loud bursting noises. The largest fissure appeared where the island had been and as the water poured from it, so the sand was thrown aside and swept away. In a few seconds, the level of the river had risen again and it spread from bank to bank. The Ganges had resumed its interrupted flow and its waters swept on as if nothing had ever happened. Every boat was capsized and it was only by a miracle that no lives were lost in my presence'.

It is possible that this appearance of the Ganges running dry was merely due to the water receding temporarily from one bank and piling up on the other, a phenomenon which was observed at several places along the Ganges, the Goghra and the Bur Gandak, and resulted presumably from wave action. At Luckee Serai one observer remarked that the water receded from midstream and sand gushed upward from the exposed river bed.

In conformity with the general rise in ground water level throughout Bihar as a result of the earthquake, the water level rose in many rivers throughout North Bihar and continued to be high for some time after the earthquake. This was especially noticed in the Balan river north of Teghra, where the level of the water was found to be three or four feet above the normal height for February. A certain amount of silting of the stream beds, as around Sitamarhi and Raxaul particularly, and the widespread closing in of the river banks with consequent restriction of the cross section of the streams may have partly, but not entirely, accounted for this general rise of river level. It was this closing in of the river banks which was largely responsible for the widespread destruction of bridges. No bridge can withstand the bodily shifting of the piers and abutments.

Captain L. E. Whitehead, Pilot Superintendent of the Lower Ganges section of the Indian General Navigation and Railway

Company, stated that the water in the Ganges was two feet six inches deeper over five shoals between Colgong and Goalundo after the earthquake. These shoals, which occasioned difficulty in navigation before the earthquake became easily negotiable. This decrease in the height of shoals is probably in conformity with the general tendency during the earthquake for the surface contours (which will include river beds) to shake down to a general level, filling in immediately adjacent depressions, a tendency which would be much more apparent in easily running river sands.

Himalaya.—There is little information about changes of level in the Himalayan rivers. Mr. Campbell Martin, of Bagaha, noticed that the Gandak river rose at Tribeni Ghat about five feet between 17·30 and 18·00 hours on the 15th January. At Bagaha the rise was recorded between 22·00 and 23·00 hours. Villagers in Nepal along the Trisuli Ganga (a tributary of the Gandak) did not notice anything extraordinary. Again, lower, down the Gandak, in Bihar, no such rise was observed. Allowing for a decrease in the rise down the river, it is nevertheless improbable that one of five feet at Tribeni Ghat would not be accompanied by some effect lower down towards the Ganges. Either the observation of five feet at Tribeni Ghat was exaggerated, or the rise that may have occurred lower down the Gandak was not noticed owing to its having occurred during the night.

No difference in level was noticed in the Tawa Khola below Udaipur Garhi.

At Mulghat (26°56′ : 87°20′), on the Tamur river, a rise of about two feet was stated to have occurred, the water remaining at an abnormal level for two days. A small *nala* flowing into the Arun river one mile south of Legua Ghat (27°08′ : 87°16′) flooded strongly just after the earthquake.

Permanent changes in drainage.

The rivers traversing this area alter their courses at the slightest provocation; the Kosi river in particular has shifted its course over a wide area from time to time during the last century. The average level of the streams is little below their banks, and even during normal monsoon rains wide areas are flooded annually. In consequence it requires little displacement to alter the course of a stream.

After the earthquake it was found that some of the water from the Bagmati was finding its way across country, north of Muzaffarpur;

this tendency of the Bagmati river to leave its old course has been found to persist in later monsoons, and new areas have been flooded. At Madhipura the earthquake had badly damaged the level bank along the Kosi river; the current immediately took advantage of this breach and swept away a large section of the embankment and it became obvious that during the succeeding monsoon the stream would add still further to this lateral erosion. The succeeding monsoon in 1934 began with heavy rainfall which gave rise to unusually severe floods. This flooding must not be attributed to changes in level due to the earthquake, although the slow manner in which the floods receded from certain areas may have been a consequence of local subsidence. Mr. Brett (1935, p. 35) reports that about 20 village sites to the north of Muzaffarpur had to be abandoned partly because the raised ground on which the villages were built had subsided and partly because the Bagmati had, in places, left its old course.

Landslides and lakes.

Landslides occurred in the mountain areas near Katmandu, Udaipur Garhi, and in Eastern Nepal.

Katmandu.—The falls around Katmandu were confined chiefly to highly weathered granite-pegmatites, which crop out on the south face of the Sheopuri Lekh, the ridge which forms the northern rim of the valley. No loss of life was recorded from them. Other minor falls were seen near Bhimphedi, in phyllites and quartzites.

Udaipur Garhi.—The hill sides in the neighbourhood of Udaipur (26°55′ : 86°32′) were everywhere scarred with rock falls (*see* Plate 27, fig. 1). These were most noticeable in gneisses and schists of the Mahabharat range to the north, where vegetation is scanty, but actually such rock falls were as common in the jungle covered Siwalik rocks to the west, south and south-east. No cases of death were reported. The falls in the Siwalik sandstones near Muksar (26°52′ : 86°23′) blocked the local *nulla* in four places, forming lakes. Two of these lakes emptied after several weeks. In March 1934, the larger of the remaining lakes was about 600 feet long with a probable maximum depth of 25 feet. The lake flowed through a small overflow channel across the slip and was rapidly silting up. There was no danger to villages lower down from a possible burst during

the ensuing monsoon, partly on account of silting and partly due to the fact that the water would have spread out to a negligible depth in a broad valley half a mile lower down.

Dharan, Dhankuta.—A landslide five miles north-west of Dhankuta (26°59′ : 87°21′) caused 30 deaths, and another nine miles distant in the same direction caused 13 deaths. The rocks that slipped here were gneisses and mica-schists. On the north side of the ridge between Dharan and Mulghat, near Dharapani, a conspicuous landslip, which had breached the path, is in shattered quartzites. It is probable that a large block of quartzite, weighing thousands of tons, will eventually topple over.

Taplejung.—There are two large areas of landslide near Taplejung (27°21′ : 87°40′). One is about three square miles in extent and lies one mile north of the village. It originated in 1927, apparently as a result of the heavy monsoon of that year. The other lies three miles to the E. S. E. of Taplejung and is said to have started in 1924. The slips due to the earthquake are quite unimportant. They are seen sporadically all the way from Taplejung to the Nepal-Darjeeling frontier, interspersed with older slips.

No landslides were noticed on the traverse through the Darjeeling district from Nepal. The great majority of the hill slopes of Darjeeling are close to the safety margin, and periodic rock-falls and slips are the consequence even in normal years, particularly during and after the monsoon. The rock is disintegrated, closely foliated gneiss (Sikkim gneiss), supporting an unconsolidated and at times rather spongy soil-cap of considerable thickness. On well-planted or forested slopes the soil is held together tolerably well, but deforestation, and excavations for stone or earth for road-making or house-building purposes have tended to produce a general instability of hill slopes at many points. Since the ground-rifts resulting from the earthquake were shallow and did not penetrate to the rock-core in the main ridge of the station, it was improbable that, except in the case of three subsidiary spurs (see details of damage in Darjeeling, page 260), any fresh danger, or predisposing cause, has been introduced for producing landslips on an extraordinary scale.

In this connection the Happy Valley landslip area was examined in company with Mr. Chambers, the Executive Engineer. This slip has caused no anxiety for the last six years or so and the earthquake of January 15th has not given rise to any further trouble

in this notoriously unstable mass of rock and debris. Evidently the precautions taken during the last few years have proved effective. This, however, is no guarantee of its continued stability, and, notwithstanding the earthquake, no drainage water should be allowed to penetrate the surrounding ground, nor should the bottom to be undercut. A rigid enforcement of all the former precautions is necessary turfing of the slope with planting of trees, stoppage of all kinds of excavation and—most important of all—water-tight lining of the jhoras (ravines) draining the immediate neighbourhood of the slipped mass. The toe of the slope at the bed of the ravine needs full protection from erosion or undermining. As an urgent additional measure of safety the Geological Survey has recommended that the unlined bed of the ravine, known as the Convent jhora, should be treated in the same manner as the Hospital and the Cutchery jhoras. Also the plot of ground called Temple Flat, on the south-east side of Cutchery jhora, needs more effective draining and dressing of the slope to prevent large areas of this ground from sliding into the ravine.

Increased flow of water in mines.

Apparently the shock was not noticed underground in the numerous collieries in Bengal and Bihar, although it was felt at the surface. These mines are situated within isoseismal VI and are some 200 miles from the epicentral tract, yet it is evident that the rocks here did receive a severe shaking for a considerable disturbance of the underground circulation of water was reported after the earthquake. In general the higher mines, that is those up the dip, had a decrease in the flow of water below the usual dry weather load, whilst the lower mines, that is those down the dip, showed a great increase, amounting to 50 to 400 per cent. more than the normal dry weather load. This increase continued until the ensuing monsoon. In some cases water appeared from old fissures which had been dry for years.

Monghyr thermal springs.

These well known hot springs, situated at Sitakund six miles from Monghyr, issue from alluvium close to an outcrop of quartzite. There has been no noticeable change in the behaviour of the springs as a result of the earthquake.

Purnea guns.

Mention may be made of the brontides, popularly known as 'Purnea guns', which are similar to the sounds often heard near Barisal, Bengal, where they are known as 'Barisal guns'. Mr. D. P. Sharma, Officiating Collector of Purnea, in a letter about the 'Purnea guns' wrote :—

'The sound is heard almost all the year round (day and night), but more particularly during the rains. Several loud reports are heard in quick succession for a few minutes. The sound ceases for some time, but is heard again after an interval of half an hour or an hour. Sometimes it is not heard for days or months.

It has been frequently heard after the earthquake also, but for about a month or so it is not being heard (6.4.34). The sound resembles that of a booming of a big gun at some distance. Sometimes one feels, when the sound is louder and nearer, as if an explosion has occurred.......... It is heard mostly in Araria and Sadar sub-divisions of this district.'

Mr. Downing, District Engineer of Purnea, took particular note of these sounds and wrote as follows :—

'For about ten days after the earthquake, Purnea guns were abnormally active and loud. I and my wife would hear them all through the night (when awake of course). Since then we have not "picked them up". On the 18th to about the 21st January we used to hear deep rumblings which would last for, or continue for, several minutes at a time..... Others have also heard deep rumblings. We have not heard them since.'

Sounds similar to the Purnea guns are heard at Biratnagar (wrongly called Gograha on the maps) near the Nepal frontier, north-west of Araria. The Hakim of Biratnagar stated that the sounds have decreased in frequency since the earthquake.

CHAPTER IV.

SEISMOMETRIC STUDY.

(S. C. Roy, D.Sc., *Director, Burma Meteorological Department.*)

Introduction.

An account is given in this chapter of a seismometric study of the disastrous earthquake of Bihar and Nepal on January 15th, 1934, and of one of its aftershocks on January 19th, based mainly on the records of the Indian stations, namely, Alipore, Agra, Dehra Dun, Colaba, Oorgaum, Kodaikanal and Colombo. The observations at these stations appear to locate the epicentre of the main shock of January 15th near 26° 18′ N. and 86° 18′ E. with the time of origin of the first preliminary tremors at 8 h. 43 m. 21 s. G. M. T. This location is in general accord with the isoseismal map of the earthquake obtained by officers of the Geological Survey of India and published in *Records of the Geological Survey of India*, Vol. LXVIII, Part 2, Plate 20, (1934). The epicentral tract enclosed by Isoseist X in their map is an elongated area about 30 Kms. wide and 130 Kms. long running east and west—the major axis of the oblong passing roughly through Sitamarhi on the west and Madhubani on the east and the central region of the tract lying near 26° 30′ N. and 85° 40′ E. The seismometric centre found in the present study falls near the eastern edge of the tract, near Madhubani. A preliminary examination of the seismograms of extra-Indian stations with epicentral distances up to about 6,000 Kms. shows that observations within this range are not in disagreement with the location of the epicentre near 26° 18′ N. and 86° 18′ E.

The Indian seismograms used in the present study are reproduced in Plates 6-15. The records of the main shock of January 15th are incomplete and unsatisfactory in many respects for a detailed study. The Milne-Shaw instruments, for which the intensity of the light-point on the photographic paper is normally adjusted so as to be suitable for recording small earth motion, failed on this occasion to register at Alipore only a few seconds after the incidence of the first preliminary tremors (Plate 6, fig. 1) and at Colaba (Plate 6, fig. 2), Kodaikanal (Plate 6, fig. 3) and Colombo shortly after the arrival of the secondary wave. The movements were, however, so great that even the Omori-Ewing type of instruments

(Plates 7-12), in spite of their low magnifications, could not record the earthquake completely at any of the Indian stations except at Oorgaum (Plate 13). The immensity of the earth motion can be judged from the fact that the string-stops used in these instruments to prevent the writing pen from going off the recorder, broke down at such a distant station as Colaba in the case of the N—S component. In spite of the limitations, the Indian records are not without value and interest and an attempt has been made to correlate them as well as possible. Most of these records were too faint for reproduction. The originals were, therefore, magnified photographically and the traces inked as faithfully as practicable. The inked copies were then reduced in size suitable for reproduction. Inaccuracies and distortions inherent in such tracing and photographic processes are probably present in the reproductions, but it may be mentioned that features of interest in the originals have been carefully compared with the reproductions.

Interpretation of Seismograms.

In order to make clear the meanings of the symbols used in the reproductions, the seismic phases important in the study of near earthquakes are briefly recounted here. Harold Jeffreys (The Earth, pp. 95-208) has shown that the primary and the secondary waves of shocks with shallow focal origin can travel to a near station along three distinct paths. The normal waves P and S travel to the observing station through the ultrabasic layer of the earth's crust, while a second pair $\bar{P}$ and $\bar{S}$ travel directly through the granitic layer. In addition to these two pairs there is a third pair $\overset{*}{P}$ and $\overset{*}{S}$ which reach the observing station through the intermediate basaltic layer. Jeffreys' diagram showing the probable paths of these pulses through the different layers of the earth's crust is reproduced below for ready reference (fig. 2).

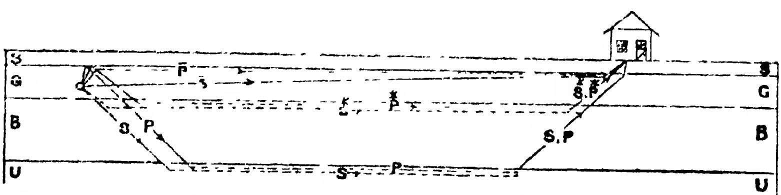

Fig. 2.—Probable paths of primary and secondary waves through crustal layers of the earth. (After Jeffreys).

An attempt has been made to identify these pulses, wherever possible, in the Indian records of the main shock of January 15th and its aftershock of January 19th. The presence of these pulses on the Alipore and Agra seismograms of the aftershock of January 19th (Plate 14, figs. 1 and 2) is unmistakable. Their identifications on the seismograms of the main shock are, however, difficult in consequence not only of the incomplete and unsatisfactory character of the records but also of their complicated nature. The complications begin from the very beginning, there being two distinct stages of P-incidence. These stages are marked on the seismograms as 1 and 2 and are referred to in the text as P_m and P_M. The first stage P_m commences with small emergent movements. The second stage P_M which occurs about 11 secs. after P_m generally begins with a sharp impetus, the movements thereafter being very large compared to P_m. An intermediate stage is also noticeable on some records about 4 to 6 secs. after P_m; but the emergence of that stage is so gradual that it would be unnecessarily complicating the present discussion to treat it as a stage distinct from P_m. The incidence of P_M occurs on the Alipore records at the expected time of arrival of $\overset{*}{P}_m$ and on the Colaba records near the time of arrival of the reflected primary wave. The stages P_m and P_M are, however, not confined only to the records of Alipore and Colaba but appear on almost all the available Indian and extra-Indian seismograms—the interval $(P_M - P_m)$ being 11 s. ± 2 s. Portions of the seismograms of Kobe are reproduced in Plate 15 to illustrate the presence of these stages on fairly distant records. The approximate constancy of the interval $(P_M - P_m)$ at near and distant stations suggests that the major crash leading to the disastrous earthquake was preceded by a minor fracture by about 11 secs. If this inference is correct, one would expect the features of the P-incidence to be repeated at the incidence of the other phases. In an earthquake, no disturbance, however, starts from rest except the first; each pulse instead of coming to an end and allowing the seismograph to come to rest is followed by another train of waves. The residual movements left by the previous pulses present difficulties in timing accurately the arrival of a new pulse on the records but it is generally possible to recognise the two stages at the incidence of each pulse—the initial oscillations (stage 1) being remarkably small compared with the final ones (stage 2). Of the Indian seismographs, it is only the Milne-Shaw instruments of Colaba and Kodaikanal

and the Omori-Ewing instruments of Agra and Oorgaum which registered true earth movements. The minor and the major stages of $\overline{P}$ are fairly clear on the Agra record (Plate 9) and of $\overline{P}$ and S on the Oorgaum records (Plate 13). The time-scales of the Milne-Shaw seismograms of Colaba and Kodaikanal are too small for a detailed scrutiny but the emergence of S-phase with comparatively small initial movements is also observable on these records. With the incidence of P_M, the Omori-Ewing type of instruments at Alipore, Dehra Dun and Colaba started making movements with the free period of their pendulums, rendering correct timing of phases on their records (Plates 7, 8, 10, 11 and 12) difficult. Occasional superpositions of true earth-movements which are noticeable on these records have been taken as a guide in timing the arrivals of phases —the initial stage of a new phase being assumed to occur generally at the end of such marked superpositions. An element of uncertainty exists in the identifications of phases on the records of Dehra Dun and Alipore for January 15th, but these identifications are generally supported by the Alipore and Agra records of the aftershock.

TABLE 5.

Readings of seismograms, January 15th, 1934.

Station.	Latitude and Longitude.	Compt.	Phase.	Time (G. M. T.)	EPICENTRAL DISTANCE.	
					Degrees.	Kilo-metres.
				H. M. S.		
1. Alipore (Calcutta)	22° 32′ N	N, E	P_m	08 44 21	4° 12′	467
	88° 20′ E	N, E	P_M & $\overset{*}{P}_m$	44 33		
		N, E	$\overline{P}_m$	44 45		
		E	S_m	45 07		
		N	$\overset{*}{S}_m$?	45 21		
		N, E	$\overline{S}$?	45 33		

TABLE 5—*contd.*

Station.	Latitude and Longitude.	Compt.	Phase.	Time (G. M. T.)	Epicentral distance. Degrees.	Epicentral distance. Kilo-metres.
				H. M. S.		
2. Agra . .	27° 08′ N	N, E	P_m	08 45 07	7° 28′	829
	78° 01′ E	N	P_M	45 17		
		N	$\bar{P}_m$	45 55		
		N	$\bar{P}_M$	46 07		
		N	S_m	46 29		
3. Dehra Dun . .	30° 18′ N	N	P_m	08 45 19	8° 18′	922
	78° 03′ E	N	P_M	45 28		
		N	$\overset{*}{P}_m$	45 35		
		N	$\bar{P}_m$	46 12		
		N	$\bar{S}_m$	46 50		
		N	$\overset{*}{S}_m$	47 24		
		N	$\bar{S}_m$	47 53		
4. Colaba (Bombay)	18° 54′ N	N, E	P_m	08 46 46	14° 28′	1607
	72° 49′ E	N	P_M	46 56		
		N, E	$\bar{P}_m$	48 22		
		N, E	S_m	49 24		
5. Oorgaum . .	12° 56′ N	N	P_m	08 46 59	15° 21′	1705
	78° 15′ E	N, E, Z	P_M	47 10		
		N	$\overset{*}{P}_m$	47 52		
		N, E, Z	$\bar{P}_m$	48 41		
		E, Z	S_m	49 48		

TABLE 5—*contd.*

Station.	Latitude and Longitude.	Compt.	Phase.	Time (G. M. T.)	Epicentral distance.	
					Degrees.	Kilo-metres.
				H. M. S.		
6. Kodaikanal .	10° 14′ N	E	P_m	08 47 36	18° 07′	2013
	77° 28′ E	E	P_M	47 47		
		E	S_m	50 55		
7. Colombo . .	6° 54′ N	E	P_m	08 48 02	20° 21′	2261
	79° 52′ E	E	P_M	48 13		
		E	S_m	51 46		
8. Medan .	3° 35′ N	N	P_m	08 48 51	25° 38′	2848
	98° 41′ E	N, E	P_M	49 02		
		N, E	S_m	53 28		
9. Hongkong . .	22° 18′ N	N	P_m	08 48 45	25° 40′	2851
	114° 11′ E	N	P_M	48 56		
		N	S_m	53 20		
10. Nanking . .	32° 03′ N	Z	P_m	08 49 14	28° 49′	3201
	118° 47′ E	Z	P_M	49 23		
		E, Z	S_m	54 18		
11. Zi-Ka-Wei . .	31° 20′ N	Z	P_m	08 49 36	31° 03′	3450
	121° 26′ E					
12. Manila .	14° 35′ N	N, E, Z	P_m	08 50 08	34° 24′	3822
	120° 59′ E	N, E	P_M	50 21		
		N, E	S_m	51 42		

TABLE 5—*contd.*

Station.	Latitude and Longitude.	Compt.	Phase.	Time (G. M. T.)	Epicentral distance.	
					Degrees.	Kilo-metres.
				H. M. S.		
13. Batavia . .	6° 11′ S	E	P_m	08 50 39	38° 06′	4233
	106° 50′ E	N, E, Z	P_M	50 48		
		N, E	S_m	56 40		
14. Kobe . .	34° 41′ N	E, N, Z	P_m	08 51 13	42° 32′	4725
	135° 11′ E	E, Z	P_M	51 26		
		N, Z	S_m	57 40		
15. Ksara . .	33° 49′ N	N	P_m	08 51 29	43° 52′	4873
	35° 52′ E	N	P_M	51 38		
		N	S_m	58 04		
16. Tokyo . .	35° 41′ N	N, E, Z	P_m	08 51 46	46° 12′	5132
	139° 45′ E	E, Z	P_M	51 58		
		E, Z	S_m	58 32		
17. Helwan . .	29° 51′ N	E	P_m	08 51 58	48° 10′	5351
	31° 20′ E	E	P_M	52 08		
		E	S_m	59 02		
18. Amboina . .	3° 42′ S	E	P_m	08 52 17	50° 23′	5598
	128° 10′ E	N, E	P_M	52 28		
		N, E	S_m	59 31		
19. Sofia . . .	42° 40° N	E	P_m	08 52 40	53° 08′	5903
	23° 20′ E	E	P_M	52 49		
		E	S_m	09 00 08		

Origin time of the earthquake of January 15th.

Readings of the seismograms used in the present study are given in Table 5. The times of arrival of P_m given originally by the Indian stations were :—

Station.	Original time of arrival of P_m
Alipore	8 h. 44 m. 18 s. G. M. T.
Agra	8 h. 45 m. 11 s. ,,
Dehra Dun	8 h. 45 m. 14 s. ,,
Colaba	8 h. 46 m. 48 s. ,,
Oorgaum	8 h. 47 m. 04 s. ,,
Kodaikanal	8 h. 47 m. 36 s. ,,

The observatories at Alipore, Agra, Colaba and Kodaikanal make daily determinations of the errors of their reference clocks by comparison with wireless time-signals from Bordeaux, Nauen or Rugby, and such determinations are also checked occasionally against star observations. There is, therefore, no reason to doubt the accuracy of the time kept at these stations. Dehra Dun also makes regular star-observations and the time of that station is equally reliable. Accurate time-keeping does not, however, by itself ensure accurate timing of phases on the seismograms. There are various factors which can give rise to appreciable differences in readings on seismograms by different observers—particularly when the time-scales are small. A scrutiny of the Dehra Dun record indicates that the original reading is about 5 secs. less than it should be. The reading originally taken appears to have been based on the assumption that the time-interval between the tracing-pen and the time-marking pen was constant. This assumption would only hold if the recording drum rotated at a uniform speed. Actually the minute-intervals on the Dehra Dun record are far from uniform. With variable speed of the drum it is probably more correct to assume that the distance between the tracing-pen and the time-marking pen is constant rather than the time-interval. With this assumption, the reading obtained for the arrival-time of P_m on the Dehra Dun record is 8 h. 45 m. 19 s. G. M. T.

P_m arrived on the Milne-Shaw records of Colaba near a minute-break and the original reading of its arrival at 8 h. 46 m. 48 s. G. M. T. was taken in the middle of the break. Subsequent examination of the Colaba records showed that the incidence of P_m should be

taken 2 secs. earlier near the beginning of the minute-break. The accepted time of arrival of P_m at Colaba is, therefore, 8 h. 46 m. 46 s. G. M. T.

Observable movements begin on the Oorgaum records at 8 h. 46 m. 59 s. on the N—S component, 8 h. 47 m. 02 s. on the E—W component and 8 h. 47 m. 04 s. on the Z component. The clock-correction of Oorgaum is not known. The arrival time of P_m at Oorgaum has been taken as 8 h. 46 m. 59 s. on the assumption that the clock-correction there was zero and that the earlier small movements were not recorded by the E—W and Z components.

Agra's reading of the time of arrival of P_m on the Omori-Ewing seismogram was 8 h. 46 m. 11 s. G. M. T. and on the Milne-Shaw seismogram 8 h. 46 m. 10 s. G. M. T. It has not been possible to scrutinise the Agra records fully for want of complete data for verification of time. It is, however, found necessary to assume a time correction of −3 s. at Agra and + 3 s. at Alipore to bring their observations in better accord with the observations of the other Indian stations. The adopted times of arrival of P_m at different Indian stations are thus :—

Station.	Adopted time of arrival of P_m.	Adopted—Original.
Alipore	8 h. 44 m. 21 s. G. M. T.	+ 3 s.
Agra	8 h. 45 m. 07 s. ,,	— 3 s.
Dehra Dun	8 h. 45 m. 19 s. ,,	+ 5 s.
Colaba	8 h. 46 m. 46 s. ,,	— 2 s.
Oorgaum	8 h. 46 m. 59 s. ,,	— 5 s.
Kodaikanal	8 h. 47 m. 36 s. ,,	0 s.

The differences under column 3 above have been explained except in the case of Alipore and Agra whose time-data could not be scrutinised. In any case these differences may be regarded as residual errors of observation which are not uncommon in seismology.

Readings of the incidence of the first stage of the secondary waves S_m have been taken at the points marked S_1 on the Indian seismograms. The readings are :—

Station.	Time of arrival of S_m.
Alipore	8 h. 45 m. 02 s. G. M. T.
Agra	8 h. 46 m. 35 s. ,,
Dehra Dun	8 h. 46 m. 57 s. ,,
Bombay	8 h. 49 m. 27 s. ,,
Oorgaum	8 h. 49 m. 47 s. ,,

To obtain the origin-time of P_m its arrival times at the Indian stations have been plotted against its duration (fig. 3). The plots of $P_m-(S_m-P_m)$ are found to lie practically on a straight line which, when extrapolated, gives the time of origin of P_m as 8 h. 43 m. 21 s. G. M. T.

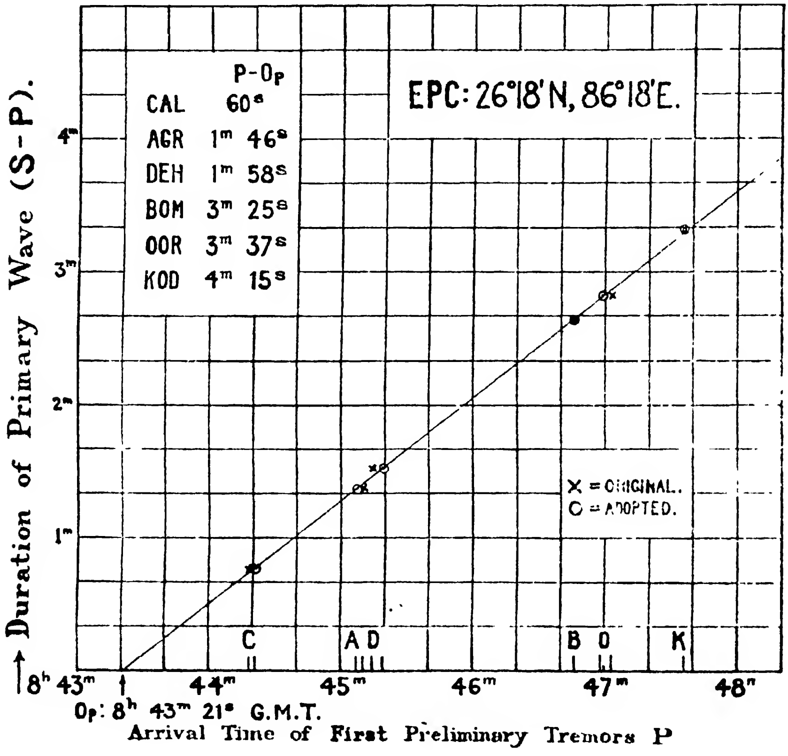

FIG. 3. $P_m-(S_m-P_m)$ graph, January 15th, 1934.

The origin-time of P_M could not be estimated by using the same method owing to uncertainty in the identifications of S_M on the Indian records. An estimate of the time can, however, be made in an indirect way. It is possible to read fairly accurately the interval (P_M-P_m) on the records of a number of Indian and extra-Indian stations. The readings of the interval for those stations

whose records are fairly clear and definite regarding the two stages are given below :—

Station.	(P_M—P_m) interval.
Alipore	12 s.
Agra	10 s.
Dehra Dun	9 s.
Oorgaum	11 s.
Kodaikanal	11 s.
Manila	13 s.
Kobe	13 s.
Tokyo	12 s.
Ksara	9 s.
Helwan	10 s.
Sofia	9 s.
Stuttgart	11 s.

From the above readings, the interval ($P_M - P_m$) is 11 s. $\pm$ 2 s. The origin-time of P_M may, therefore, be taken as 8 h. 43 m. 32 s. G. M. T.

Seismometric epicentre of the earthquake of January 15th, 1934.

Taking OP_m time as 8h. 43m. 21s, the ($P_m - OP_m$) intervals for the Indian stations are :—

Station.	$P_m - OP_m$.
Alipore	1 m. 0 s.
Agra	1 m. 46 s.
Dehra Dun	1 m. 58 s.
Colaba	3 m. 25 s.
Oorgaum	3 m. 38 s.
Kodaikanal	4 m. 15 s.

The method used for the location of the epicentre was to find out by trial a place so situated that the foregoing observations lie on a smooth time—distance curve practically straight for epicentral distances between 4° and 15°. The formula used in the trial for the calculation of epicentral distance was the usual formula of Professor H. H. Turner :—

$$(2 \sin \Delta/2)^2=(a-A)^2+(b-B)^2+(c-C)^2$$

where a, b, c are the constants for the seismological stations and A, B, C are the constants for the epicentre determined by their latitudes and longitudes. The values of a, b, c for the Indian stations are given below for ready reference.

	a	b	c
Alipore	+ ·0269	+ ·9234	+ ·3832
Agra	+ ·1854	+ ·8710	+ ·4560
Dehra Dun	+ ·1787	+ ·8445	+ ·5048
Colaba	+ ·2795	+ ·9039	+ ·3239
Oorgaum	+ ·1985	+ ·9543	+ ·2239
Kodaikanal	+ ·2138	+ ·9605	+ ·1777

The Indian seismological data are found to fit in best if the epicentre of the minor stage of the earthquake is placed near 26° 18′ N. and 86° 18′ E., the corresponding values of A, B, C being A= + ·0578 B= + ·8945 and C= + ·4431.

The distances of stations from 26° 18′ N. and 86° 18′ E. computed by using Professor Turner's formula, are given in Table 5. The time—distance curves for P_m and S_m up to 6,000 Kms. are shown in fig. 4 The general smoothness of the curves with observations on the east, west and south seems to indicate that the placing of the seismometric epicentre of the minor stage of the earthquake near 26° 18′ N. and 86° 18′ E. could not be greatly in error.

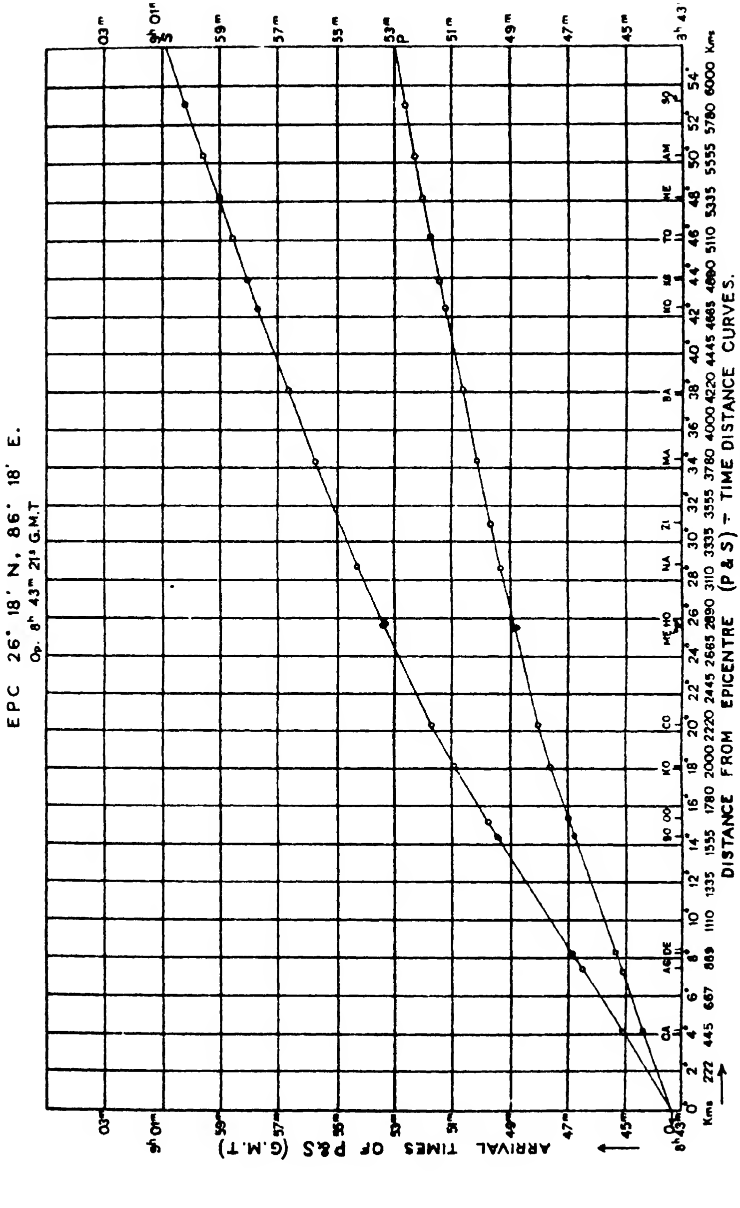

Fig. 4.—Time distance curves for P_m and S_m.

An estimate of the seat of the major-stage can also be made by the use of the trial method. Taking the origin-time to be 8 h. 43 m. 32 s. G. M. T., the (P_M—O_{P_M}) intervals for the Indian stations are :—

Station.	P_M—O_{P_M}.
Alipore	1 m. 1 s.
Agra	1 m. 45 s.
Dehra Dun	1 m. 56 s.
Colaba	3 m. 44 s.
Oorgaum	3 m. 38 s.
Kodaikanal	4 m. 15 s.

These data are found to agree with the location of the major stage of the earthquake near 26° 21′ N. and 86° 12′, E., the epicentral distances of the Indian stations being :—

Station.	Δ (Degrees).	Kms.
Alipore	4° 17′	476
Agra	7° 23′	820
Dehra Dun	8° 11′	909
Colaba	14° 25′	1,603
Oorgaum	15° 21′	1,705
Kodaikanal	18° 08′	2,015

This location of the seat of the major stage is also in accord with the observed (P_M—P_m) interval at the extra-Indian stations. The value of the interval is 11 s. ± 2 s., the highest value of 13 s. being observed at Manila and Kobe, and the lowest value of 9 s. at Dehra Dun, Ksara and Sofia. Observations of (P_M—P_m) have been made with care and the uncertainties in their measurements should not be more than ± 1 s. It is, therefore, of interest to note the general tendency of the interval to have slightly higher values at stations to the east and south-east and comparatively lower values at stations to the west and north-west of the epicentre of the minor stage. If this tendency is genuine, the seat of the major stage must have been 10 to 15 kms. to the north-west of the minor stage.

Seismometric epicentre of January 15th in relation to field observation.

As pointed out in the Introduction, the epicentral tract enclosed by Isoseist X covers a vast elongated area about 30 Kms. wide and 130 Kms. long with its central region near 26° 30′ N. and 85° 48′ E., between Madhubani and Sitamarhi. The seismometric centres of both the minor and the major stages, instead of lying more centrally on the epicentral tract, fall on its eastern edge near Madhubani. Any appreciable shifting of the epicentres towards the central region of the tract gives systematically high speeds of seismic waves to stations to the east and systematically low speeds to stations to the west. Accepting, therefore, the seismometric evidence for an initial minor failure near 26° 18′ N. and 86° 18′ E. leading through an intermediate stage to the major crash near 26° 21′ N. and 86° 12′ E. after about 11 secs., it is natural to enquire if other crashes could not have subsequently occurred in the same fault-surface or in the neighbouring faults with the transference of the elastic stresses no longer supported at the scene of the major crash. Such an occurrence appears very probable but the transfer of elastic stress from point to point is not simultaneous but requires time, depending on the elasticity and density of the rock. It is not, therefore, possible for stresses and hence fractures to extend at a rate greater than that of the fastest elastic waves which are of the compressional type. It follows that when several crashes occur at different parts of a fault or in the neighbouring faults, the seismic waves that will arrive first at a station not very close to the epicentre will be those radiating from the earliest crash, even if the station be nearer the origin of the later crashes. This point has been discussed at length by Professor A. C. Lawson and others (1908) in their report on the California Earthquake of April 18th, 1906. It is thus clear that, if the later crashes were comparatively less severe, the waves originating from them would be masked by those from the major crash and would not be easily distinguishable on the seismograms. It is of interest, however, to note that both the field observations and the seismometric observations agree in showing that after the major crash near Madhubani, the transfer of the unsupported stresses occurred more to the W. N. W. towards Sitamarhi rather than to the E. S. E., towards Purnea.

In addition to the main epicentral tract between Madhubani and Sitamarhi there are two small areas on the isoseismal map (Plate 1) of the earthquake of January 15th—one around Monghyr and the other in the Nepal valley to the south-east of Katmandu—where the intensity reached the degree of X. It is well known that the action of an earthquake depends largely on the geological character of the ground and the nature of the structures on it. High 'apparent intensity' judged from the damage and dislocation on the surface may not, therefore, always coincide with high 'intrinsic intensity'. This fact was fully demonstrated by the critical investigations of Professor A. C. Lawson and others (1908), on the areal distribution of damage done by the California Earthquake of April 18th, 1906. The apparent high intensity in the Nepal Valley and the Monghyr area may be due only to the nature of the geologic materials there. The seismometric evidence is clearly against the origin of any independent shocks in those areas before or simultaneously with the origin of the major crash, but does not preclude the possibility of comparatively less severe ruptures occurring there subsequently[1].

Aftershock of January 19th.

A number of aftershocks have been registered by the seismographs at Alipore and Agra but with the exception of the one of January 19th none of them were strong enough to be recorded fully from the beginning of the normal P-wave. The records begin in some cases with the incidence of $\overset{*}{P}$ or $\bar{P}$ and in most cases with the incidence of S or even $\bar{S}$. A thorough scrutiny of the records is, therefore, necessary if they are used for the estimation of the origin of the aftershocks. It has not been possible for the writer to undertake such a scrutiny. The aftershock of January 19th was sufficiently strong to be recorded fully also by the Milne-Shaw instruments at Colaba. With complete records at three stations, the origin of this aftershock can be estimated with a fair degree of confidence. The readings of the seismograms (Plate 14) of Alipore, Agra and Colaba for January 19th are given in Table 6.

[1] *Geological Survey.*—This conclusion agrees with that independently arrived at as a result of our field examination (*see* pp. 80, 81 and 149).

TABLE 6.

Readings of seismograms, January 19th, 1934.

Station.	Compt.	Phase.	Time (G. M. T.)			Epicentral distance.	
						Degrees.	Kilometres.
			H.	M.	S.		
1. Alipore	E	P	18	50	51	4° 17′	476
	E	$\overset{*}{P}$		51	04		
	E	$\overline{P}$		51	16		
	E	S		51	39		
	E	$\overset{*}{S}$		51	53		
	E	$\overline{S}$		52	07		
2. Agra	N	P	18	51	37	7° 28′	830
	N	$\overset{*}{P}$		52	00		
	N	$\overline{P}$		52	25		
	N	S		53	00		
	N	$\overset{*}{S}$		53	27		
	N	$\overline{S}$		53	54		
3. Colaba	N, E	P	18	53	16	14° 30′	1,611
	N, E	S		55	55		
	N, E	$\overset{*}{S}$		56	53		
	N	$\overline{S}$		57	49		

These data place the epicentre of the aftershock of January 19th approximately near 26° 24′ N. and 86° 18′ E., giving the following epicentral distances:—

Station.	Δ Degrees.	Kms.
Alipore . . .	4° 17′	476
Agra . . .	7° 29′	832
Bombay . . .	14° 30′	1,611

The place of origin of the aftershock of January 19th was, therefore, very close to the seismometric epicentre of the main earthquake of January 15th.

The O_p time of the aftershock obtained graphically by plotting arrival times of P against (S—P) intervals (fig. 5) is 18 h. 49 m. 50 s. G. M. T. The $(P—O_p)$ intervals are :—

Station.	$P—O_p$
Alipore . . .	1 m. 1 s.
Agra . . .	1 m. 47 s.
Bombay . . .	3 m. 26 s.

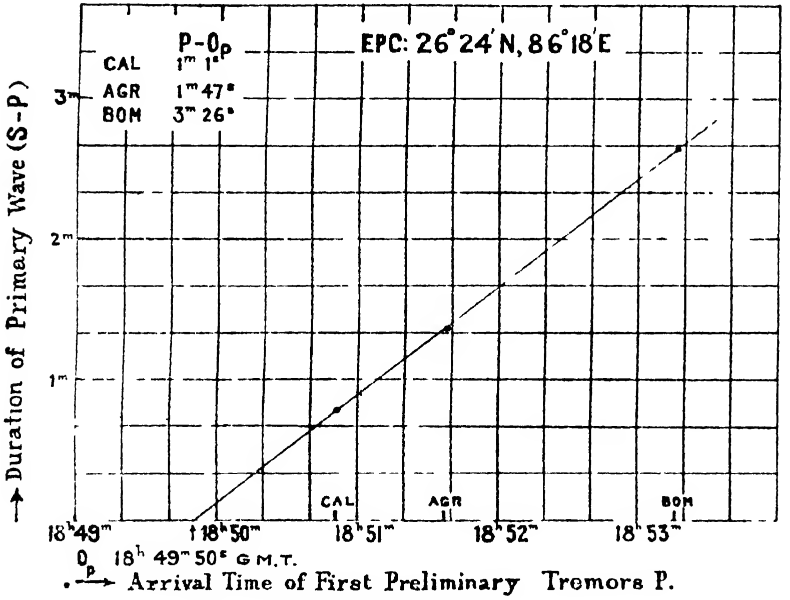

FIG. 5. S—(S—P) graph, January 19th.

Although it is not possible to estimate the exact origin of the other aftershocks without a fuller scrutiny of the seismograms of Alipore and Agra, a comparison of the records of these stations enables one to sort out the aftershocks of the Bihar earthquake of

January 15th. A list is given below of those aftershocks which were registered by instruments both at Alipore and Agra.

Date.	Number of Aftershocks.
January 15th . . .	18
January 16th . . .	6
January 17th . . .	3
January 18th . . .	1
January 19th . . .	1
February 4th . . .	1
February 8th . . .	1
February 17th . . .	1
April 8th . . .	1
April 13th . . .	1

After April, no aftershock appears to have been sufficiently strong to be registered both at Alipore and Agra. The list given here is a selective one, but it indicates clearly that the frequency of aftershocks registerable by instruments at a distance of 450—850 kilometres declined very rapidly. This rapid decline appears to suggest that nearly complete relief was provided by the main shock of January 15th.

Velocities of travel of compressional and distortional waves through three layers of the earth's crust.

Taking O_p time as the zero time, the transit times of P, $\overset{*}{P}$, $\bar{P}$, S, $\overset{*}{S}$ and $\bar{S}$ to Alipore, Agra, Dehra Dun, Colaba and Oorgaum are computed in Table 7.

TABLE 7.

Transit times of P, $\overset{*}{P}$, $\bar{P}$, S $\overset{*}{S}$, and $\bar{S}$.

Station.	Date.	Kms.	$P\text{-}O_p$	$\overset{*}{P}\text{-}O_p$	$\bar{P}\text{-}O_p$	$S\text{-}O_p$	$\overset{*}{S}\text{-}O_p$	$\bar{S}\text{-}O_p$
1. Alipore .	Jan. 15	467	60s.	71s.	84s.	106s.	120s.	132s.
Alipore .	Jan. 19	476	61s.	74s.	86s.	109s.	123s.	137s.
2. Agra .	Jan. 15	830	106s.	..	154s.	188s.	..	..
Agra .	Jan. 19	830	107s.	130s.	154s.	189s.	217s.	244s.
3. Dehra Dun	Jan. 15	922	118s.	144s.	171s.	209s.	243s.	272s.
4. Colaba .	Jan. 15	1607	205s.	..	301s.	363s.	.	..
Colaba .	Jan. 19	1611	206s.	..	..	365s.	423s.	579s.
5. Oorgaum .	Jan. 15	1705	218s.	271s.	320s.	387s.	..	..

Owing to insufficiency of observations, the available data of January 15th have been combined with those of January 19th to obtain average time-distance curves for the six pulses (fig. 6). For

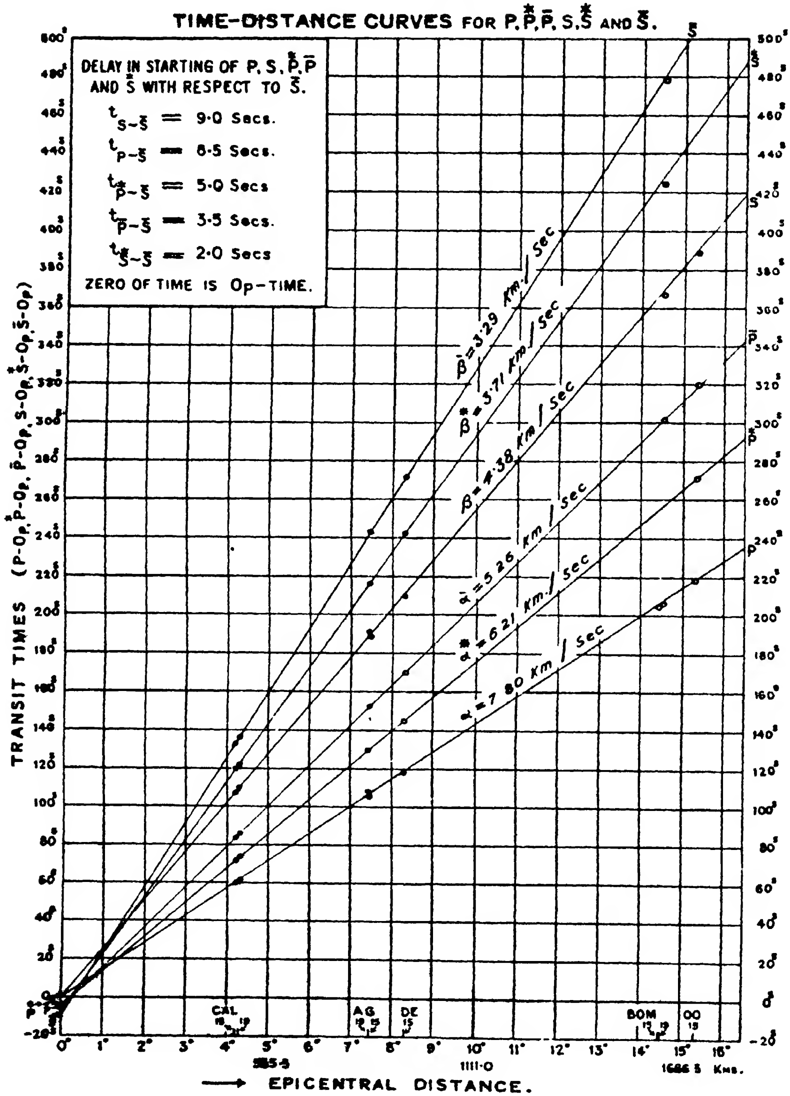

FIG. 6.—Average time-distance graphs of P, $\overset{*}{P}$, $\bar{P}$, S, $\overset{*}{S}$ and S for the Bihar Earthquake of January 15th and its aftershock of January 19th.

all practical purposes, the curves are straight lines. A slight curvature-effect of the earth appears to be observable at the distances of Colaba and Oorgaum (14°—15°) and hence a greater weight has been given to observations at nearer stations in drawing the lines.

The extrapolation of the time-distance curves shows that S is the first wave to start from the origin, the other pulses apparently starting later. The apparent delays in starting of the various pulses with respect to $\bar{S}$ are :—

$t_{(S\sim\bar{S})}=9{\cdot}0$ secs, $t_{(P\sim\bar{S})}=8{\cdot}5$ secs, $t_{(\overset{*}{P}\sim\bar{S})}=5{\cdot}0$ secs,

$t_{(\bar{P}\sim\bar{S})}=3{\cdot}5$ secs, and $t_{(\overset{*}{S}\sim\bar{S})}=2{\cdot}0$ secs.

This interesting feature of the graphs will be discussed later. Below are given the average velocities of travel (α, $\overset{*}{\alpha}$, $\bar{\alpha}$) of the three compressional waves (P, $\overset{*}{P}$, $\bar{P}$) and those (β, $\overset{*}{\beta}$, $\bar{\beta}$) of the three distortional waves (S, $\overset{*}{S}$, $\bar{S}$) calculated from the time-distance curves of the Bihar earthquake :—

Velocities of Compressional waves in the Gangetic valley.	Velocity of Distortional waves in the Gangetic valley.
$\alpha=7{\cdot}80$ Km/sec. (P).	$\beta=4{\cdot}38$ Km/sec. (S).
$\overset{*}{\alpha}=6{\cdot}21$ Km/sec. ($\overset{*}{P}$).	$\overset{*}{\beta}=3{\cdot}71$ Km/sec. ($\overset{*}{S}$).
$\bar{\beta}=5{\cdot}26$ Km/sec. ($\bar{P}$).	$\bar{\alpha}=3{\cdot}29$ Km/sec. ($\bar{S}$).

It is of interest to compare these values with those found by Jeffreys (The Earth) for the continent of Europe. They are :—

Velocities of Compressional waves in Europe.	Velocities of Distortional waves in Europe.
$\alpha=7{\cdot}8$ Km/sec.	$\beta=4{\cdot}35$ Km/sec.
$\overset{*}{\alpha}=6{\cdot}2$ to $6{\cdot}3$ Km/sec.	$\overset{*}{\beta}=3{\cdot}7$ Km/sec.
$\bar{\gamma}=5{\cdot}4$ to $5{\cdot}6$ Km/sec.	$\bar{\beta}=3{\cdot}3$ Km/sec.

Except for $\bar{\alpha}$, the speeds of waves for the Gangetic valley and the continent of Europe are in close agreement. The speed of the compressional wave through the uppermost layer is definitely less in the Gangetic valley. In spite of some uncertainties in the timing of phases on the seismograms, the writer is satisfied as regards the reality of the tendency for lower values of $\bar{\alpha}$ in the case of the Bihar

earthquake. There is, however, no corresponding reduction in the speed $\bar{\beta}$ of the distortional wave. These facts appear to support the theory that the fundamental shear-wave $\bar{S}$ follows a direct path through the granitic layer from the focus to the observing station whereas the compressional wave $\bar{P}$, which is derived from $\bar{S}$ by reflection at the base of the sedimentary layer, follows a path near the top of the granitic layer, the lowering of the speed of $\bar{P}$ being explained by the occasional presence of the Gangetic alluvium in its path.

Depth of Focus of the Bihar Earthquake.

It should be made clear at the very outset that the words 'focus' and 'focal depth' are used here in a restricted sense and that they refer to the point or rather the limited area where the initial minor failure leading to the disastrous earthquake of January 15th occurred. The enormous extent of the epicentral tract and the existence of secondary areas of high intensity together with the complicated nature of the seismograms of January 15th led the writer to examine the records of extra-Indian stations with a view to finding out if phases characteristic of deep-focus earthquakes are present in them. The attempt has proved unsuccessful and the writer is of opinion that no deep-focus interpretation of the records is possible. S. K. Banerji (1925, pp. 65-80) has shown that the energy of Rayleigh waves decreases rapidly as the depth of focus increases. The development of L-waves on the records of the Bihar earthquake (shown clearly by the seismograms of Oorgaum, Plate 13) constitutes, therefore, further proof against any deep-focus interpretation. On the other hand, the phases identified on the Indian records, if correct, show definitely that the main earthquake of January 15th and its aftershock of January 19th had their origin in the uppermost layer of the earth's crust.

The correct estimation of the focal depth of an earthquake is the most difficult problem in seismology. Several methods have been used for the purpose, but all entail uncertainties due to lack of sufficient and accurate data. An estimate of the focal depth of the Bihar earthquake can be made by using Jeffrey's method based on the apparent delay in start of $\bar{P}$ with respect to $\bar{S}$. Jeffreys has shown that this delay is related to the focal depth, d, as follows :—

$$d = \frac{\bar{\beta}}{\left(1 - \frac{\bar{\beta}^2}{\bar{\alpha}^2}\right)^{\frac{1}{2}}} \cdot t_{(\bar{P} \sim \bar{S})}$$

where $t_{(\bar{P}\sim\bar{S})}$ represents the apparent delay in start of $\bar{P}$ with respect to $\bar{S}$.

For the Bihar earthquake of January 15th and its aftershock of January 19th,

$$\bar{\beta}=3{\cdot}29 \text{ Km/sec.}$$
$$\bar{\alpha}=5{\cdot}26 \text{ Km/sec.}$$
$$\text{and } t_{(\bar{P}\sim\bar{S})}=3{\cdot}5 \text{ secs.}$$

These values place the origin of the Bihar shocks at a depth of 14·8 kilometres.

Thickness of the granitic and the basaltic layers in Bihar.

Jeffreys has shown also that the thickness of the uppermost granitic layer H_g can be estimated from the apparent delay in start of $\overset{*}{P}$ with respect to $\bar{P}$ by using the following formula :—

$$2\ H_g = d + \frac{\bar{\alpha}}{\left(1-\dfrac{\bar{\alpha}^2}{\overset{*}{\alpha}^2}\right)^{\frac{1}{2}}} \cdot t_{(\overset{*}{P}\sim\bar{P})}$$

For the Bihar shocks—

$$d=14{\cdot}8 \text{ Kms.}$$
$$\bar{\alpha}=5{\cdot}26 \text{ Km/sec.}$$
$$\overset{*}{\alpha}=6{\cdot}21 \text{ Km/sec.}$$
$$t_{(\overset{*}{P}\sim\bar{P})}=1{\cdot}5 \text{ secs.}$$

With these values, the thickness of the granitic layer in Bihar comes out at 14·8 Kms. No undue importance need be attached to the exact coincidence of the figures for the focal depth and the thickness of the uppermost layer but the seismometric evidence may be taken to point to the conclusion that the primary cause of the disastrous Bihar earthquake of January 15th lay near the interface of the granitic and the basaltic layers.

An estimate of the thickness H_B of the intermediate basaltic layer can also be made from the apparent delay in start of P with respect to $\overset{*}{P}$ by using the relation :—

$$2\ H_B = d + \frac{\overset{*}{\alpha}}{\left(1-\dfrac{\overset{*}{\alpha}^2}{\alpha^2}\right)^{\frac{1}{2}}} \cdot t_{(P\sim\overset{*}{P})}$$

For the Bihar shocks—

$$d = 14{\cdot}8 \text{ Kms.}$$
$$\overset{*}{\alpha} = 6{\cdot}21 \text{ Km/sec.}$$
$$\alpha = 7{\cdot}80 \text{ Km/sec.}$$
$$t_{(P \sim P^*)} = 3{\cdot}5 \text{ secs.}$$

From these values, the thickness of the basaltic layer in Bihar is found to be equal to 25·4 Kms.

Constitution of crustal layers in Bihar.

The bulk-moduli, k, computed from the velocities of travel of the compressional and the distortional waves in the Gangetic valley are :—

	$\alpha \times 10^{-5}$ C. G. S.	$\beta \times 10^{-5}$ C. G. S.	$\frac{k}{\rho} \times 10^{-10} = (\alpha^2 - \frac{4}{3}\beta^2) \times 10^{-10}$ C. G. S.
Upper layer . .	5·26	3·29	13·0
Intermediate layer .	6·21	3·71	20·2
Lower layer . .	7·80	4·38	35·3

The values obtained by Jeffreys for the continent of Europe are :—

	$\alpha \times 10^{-5}$	$\beta \times 10^{-5}$	$\frac{k}{\rho} \times 10^{-10}$ (C. G. S.).
Upper layer . .	5·4	3·3	14·7
	5·6	3·3	16·9
Intermediate layer .	6·3	3·7	21·4
Lower layer . .	7·8	4·35	35·6

The computed values of the bulk-moduli for the intermediate and the ultrabasic layers of the Gangetic valley are very close to those for the continent of Europe. The bulk-modulus obtained for the upper layer of the Gangetic valley is, however, comparatively low and is due to the low value of the velocity of travel of the compressional wave through that layer in Bihar.

Jeffreys (The Earth, p. 102) has given a table of the bulk-moduli of rocks determined experimentally in the Geophysical Laboratory at Washington. An extract of the table is given here for ready reference in Table 8. The laboratory values refer to ordinary

temperatures and pressures of 2×10^9 C. G. S. and 10^{10} C. G. S. corresponding to depths of 7 Kms. and 33 Kms. respectively in the crust.

TABLE 8.

Bulk moduli of rocks (from Jeffreys).

Rock.	Density.	$\frac{k}{\rho} \times 10^{-10}$ C. G. S.	Pressure (C. G. S.).
Obsidian	2·33	15 1	Mean for the range 2×10^9 to 10^{10}
Granite	2·61	18·3	2×10^9 (7 Kms).
Tachylite	2·85	24·0	Mean for the range 2×10^9 to 10^{10}
Diorite	2·74	22·8	2×10^9 (7 Kms).
	2 78	24 3	10^{10} (33 Kms).
Gabbro	3·05	27·8	2×10^9 (7 Kms).
	3·08	28·2	10^{10} (33 Kms).
Dunite	3·32	38·3	10^{10} (33 Kms).

The seismometric value for the bulk-modulus of the upper layer is appreciably below that for granite found experimentally in the laboratory. But the existence of the granitic layer is definitely known and Jeffreys explained the low seismometric value as being solely due to the effect of temperature within the granitic layer. The temperature-effect may not, however, be the only cause. The occasional presence in the path of **P** of rocks with bulk-moduli lower than that of granite may also be a contributing factor.

As for the lower layer, the only rock that is known to give the requisite value for $\frac{k}{\rho}$ is dunite. Taking the seismometric value as 35·3 and the laboratory value as 38·3 for dunite the lowering in the value of bulk-modulus due to temperature may be roughly estimated as 8 per cent. If the degree of temperature-effect were nearly the same in the intermediate layer, the seismological evidence is in favour of preponderance of diorite and tachylite in that layer over gabbro, as already pointed out by Jeffreys.

Summary.

The main conclusions may be summarised :—

1. The earthquake of January 15th was initiated by a minor failure near 26° 18′ N. and 86° 18′ E., the time of origin of the first preliminary tremors being 8 h. 43 m. 21 s. G. M. T[1]. The culminating major crash, which occurred about 11 secs. after the initial minor rupture and about 5 secs. to 7 secs. after an intermediate stage, has its origin near 26° 21′ N. and 86° 12′ E. close to Madhubani. The progression of the fractures towards the W. N. W. from the minor to the major stage suggests that the stresses, no longer supported at the origin of the major crash, were transferred from the Madhubani area more towards Sitamarhi than towards Purnea.

2. The epicentre of the aftershock of January 19th is located near 26° 24′ N. and 86° 18′ E., which is close to the seismometric epicentre of the main shock.

3. A list of the aftershocks which were registered by instruments both at Alipore and Agra indicates that their frequency declined very rapidly. This rapid decline is interpreted to mean that nearly complete relief was afforded by the main shock of January 15th.

4. The extraordinary development of long waves and the presence on the Indian seismograms of pulses characteristic of near earthquakes with shallow focal depth, suggest that the main earthquake of January 15th originated in the uppermost layer of the earth's crust.

5. The average time-distance curves obtained by combining the observations of January 15th and 19th for the compressional waves and the distortional waves through the granitic, basaltic and ultrabasic layers of the earth's crust, give the following velocities of travel for the different pulses :—

	Velocity of Compressional wave.	Velocity of Distortional wave.
Granitic layer	5·26 Km/sec.	3·29 Km/sec.
Basaltic layer	6·21 Km/sec.	3·71 Km/sec.
Ultrabasic layer . . .	7·80 Km/sec.	4·26 Km/sec.

[1] *Geological Survey.*—In our Preliminary Account of the earthquake, which was based on a less detailed analysis of the seismograms, we provisionally adopted for the time of origin a figure of 8 hrs. 43 m. 15 s. G. M. T. *Rec. Geol. Surv. Ind.*, LXVIII, p. 213, (1934).

The low value found for the velocity of the compressional wave through the uppermost layer is explained as being due to the occasional presence of the Gangetic alluvium in the path of the wave near the top of the granitic layer.

6. The focal depth and the thicknesses of the uppermost and the intermediate layers of the earth's crust in Bihar have been calculated from the apparent delays in starting of the various pulses with respect to the fundamental distortional wave travelling directly from the focus to the observing station. The values found are :—

Focal depth	**14·8 Kms.**
Thickness of granite	**14·8 Kms.**
Thickness of basalt	**25·4 Kms.**

It is concluded that the primary cause of the Bihar earthquake of January 15th lay near the interface of the granitic and the basaltic layers.

7. The seismometric values found for the bulk-moduli of the crustal layers in Bihar are :—

	$\frac{k}{\rho} \times 10^{-10}$ C. G. S.
Granitic layer	13·0
Basaltic layer	20·2
Ultrabasic layer	35·3

In conclusion, the writer wishes to record his indebtedness to the Directors of a large number of seismological institutes who have made the present study possible by giving loan of photostat copies or originals of seismograms relating to the earthquake. The writer is also grateful to Dr. C. W. B. Normand, Director-General of Observatories, India, for his continued keen interest in the work.

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CHAPTER V.

SEISMOLOGICAL OBSERVATIONS BY THE GEOLOGICAL SURVEY OF INDIA.

(J. A. DUNN.)

Location of the epicentre and focus.

One of the principle objects of the Geological Survey investigations was to locate the epicentre from the evidence provided by the graded intensities of damage in the field. Such observations can, of course, lead merely to the delineation of an epicentral tract, in contrast to the point location on mathematical grounds, determined by seismometric methods. The elongated epicentral tract, enclosed by isoseismal X, delineated by the geological survey, indicated therefore, the surface trace of the sub-alluvial fracture, whereas Dr. Roy's epicentres indicate two successive positions from which dislocation actually commenced and spread along the plane of fracture. The suggestion is of a dislocation commencing E. S. E. of Madhubani and spreading rapidly towards the W. N. W. with high intensity, contrasting with an extension to the south-east of decidedly less intensity.

The term " focus " must be limited to the point at which rupture started along the plane of fracture. We find no reason to disagree with Dr. Roy's calculation of the shallow nature of the focus. The narrow elongated nature of the epicentral tract indicates at once a crustal fracture which reached up to the sub-alluvial surface.

Significance of the trend of the isoseismals.

The elliptical traces of the isoseismals point to the linear nature the centrum. A striking feature of the isoseismals IX-VI is the close proximity to each other of the curves to the north-west, east and

south-east of the area affected by the earthquake and their gradual opening out at the western end.

The pronounced indentations and the close similarity of the curves on their eastern sides form a conspicuous feature—although in case of isoseismal VI, from the meagre evidence at our disposal, this irregularity could be modified as is shown by dotted lines in the map, Plate 2. North of the Ganges the easterly bulge of isoseismal IX at Purnea, the eastern-most limit of the slump zone, is repeated in isoseismal VI north-east of Dhubri suggesting an extension of the fractured zone in this direction up the Brahmaputra valley. The pronounced indentation of isoseismal VI along the western edge of the Garo Hills finds a replica in the westward indentation of isoseismals VII and VIII west of Dinajpur and Katihar respectively. Further south the corresponding bulges in isoseismals VIII-VI are found east of Bhagalpur, west of Malda and east of Netrokona respectively, thus providing a continuation of the Patna-Monghyr belt. Further, the zone of higher intensity within isoseismal VII, extending from Allahabad through Gaya to Dumka, has a correspondingly conspicuous bulge of isoseismal VI to the west towards Bundi in Rajputana, and to the east isoseismal VI extends to Dacca; this zone from Bundi to Dacca, some 900 miles in length, is a remarkable feature of the earthquake.

We have already mentioned the peculiar local increase in intensity at Cuttack and the isolated area of decrease north-east of Gauhati. The increase at Cuttack may be related to the deltaic conditions at the mouth of the Mahanadi, and the patch of decreased intensity in the Brahmaputra valley may arise from a local thinning of the alluvium; on the other hand, both may be a part of the peculiar more or less regular alternation in degree of severity outward from the epicentral tract of North Bihar, an alternation which includes also the Patna-Monghyr belt, the Bikram-Bihar and Allahabad-Dumka zones and perhaps even the Nepal valley. This feature is best illustrated by a graph, fig. 7, which may be taken to diagrammatically represent the variation in intensities from Katmandu, through the epicentral region and south over the Peninsula. For ordinates, McAdie's accelerations for each isoseismal are used, and, excluding the zonal increase in intensity, the outer isoseismals give a smooth hyperbole. On this, are superposed for Sitamarhi, Katmandu, Muzaffarpur and Monghyr, the actual accelerations determined during the field work. For the Bikram-Bihar,

Allahabad-Gaya and Cuttack zones, the assumed acceleration has been taken as below that of McAdie for the next higher isoseismal.

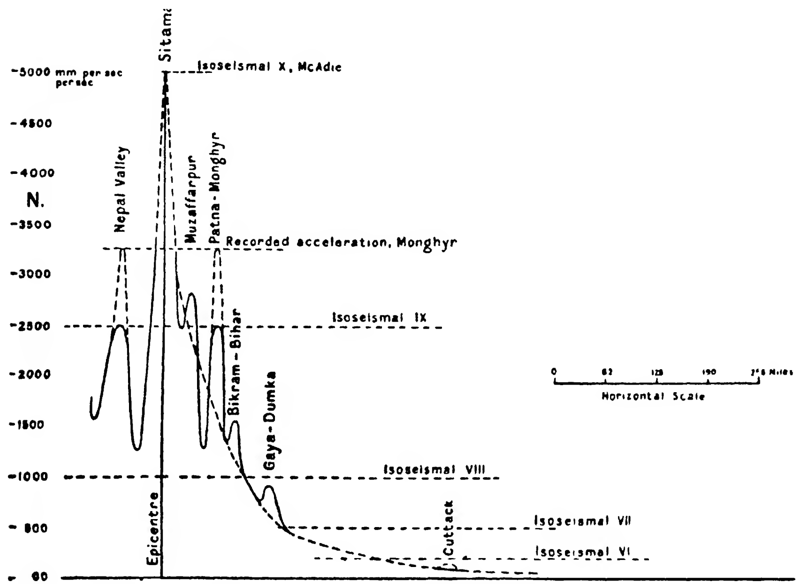

FIG. 7.—Acceleration-distance graph, Bihar-Nepal earthquake.

The isoseismal map clearly shows that these alternating zones are not *concentric* to the epicentre, but (apart from the Nepal valley area) are roughly *parallel* to the trend of the elongated epicentral region. Although it is probable that the high intensity within the Nepal valley is due to the alluvial nature of that tract, the same interpretation of sub-soil control cannot be made for the other zones. The rivers here run more or less from north to south, towards the east-flowing Ganges, and all the information which we have available points to a widespread distribution of the alluvial beds; if anything, they are aligned north-south, such as the thick sand bed of Purnea district. The zones cross the river trends at right angles, except, of course, the Patna-Monghyr belt which is parallel to the trend of the Ganges, but even the lateral extension of this zone crosses the rivers at right angles. Furthermore, control of the intensities by sub-alluvial ridges and valleys in the

basement rock cannot be an explanation, for the Allahabad-Dumka belt crosses alluvium and Archaean country indiscriminately, and continues west with diminished intensity over Archaeans to Bundi. Neither can these high intensity zones be interpreted as due to sub-crustal peculiarities in movement of seismic waves radiating from the focus, or to wave interference, for in that case a more concentric arrangement of these belts would be expected.

Elsewhere it is pointed out that, away from the epicentre and particularly to the south, the movement during the shock tended to be more or less east and west, in a general way parallel to the trend of isoseismal X, and parallel also to the trend of the several zones of increased intensity. This indicates that somewhat polarised shear waves, oscillating parallel to the epicentral trend, were the dominant movements. This fact is profoundly significant for it implies an east-west component as the principal movement along the supposed fracture which was the source of the earthquake.

We have then to find an explanation for the peculiar features noted in this section:—(*a*) the parallel zones of gradually diminishing high intensity and (*b*) the general east-west movement under the action of shear waves.

Neither of these facts are consistent with a point origin, and in our opinion they can only imply a plane of dislocation. This is in contrast to experience in Japan where it has been found that the seismic origin of most earthquakes is small, mere points on a map, and origins of linear form or irregular shape are rare. Indeed, this has led Nobuji Nasu (1935, p. 2) to say—"The focal-line or focal plane, hitherto regarded as common forms of earthquake origin, cannot exist in reality". He also remarked (1935, p. 1.):—"......the indications are that earthquakes occur as a result of changes in the physical and chemical properties of rocks, and not, as has been usually regarded, as the result of fractures in the earth's crust through sudden yielding to slow increasing strains." On this view the faults are nothing more than the mere accompaniments of these sudden changes that take place in the rocks at far greater depths than originally imagined, Nasu's view following Oldham's explanation of bathyseisms based upon Fermor's theory of changes in the eclogite shell. However, Nasu's insistence on a *point* of origin for the destructive seismic waves receives no support from such extensive earthquakes as the Bihar shock or the great San Francisco shock of 1906. For these a focal-plane is definite enough,

and was certainly conclusively proved for the San Francisco shock where a movement of up to 21 feet along the San Andreas fault, 270 miles in strike length, was detected. Whatever may be the experiences in Japan the theory of point origins should not be lightly applied to other regions, and we discard it for the Bihar shock. The fact that the Bihar fracture *commenced* from a point, as discussed elsewhere, is quite a different matter from the above considerations.

We have, then, retained the view of a facture as the origin of the Bihar earthquake, in keeping with the trend of the isoseismals, and the direction of oscillation of the shear waves indicates that movement was largely horizontal, along the fault. Such a fault may be aptly termed a *lateral shear fault*, but Bailey Willis prefers the term *strike-slip fault*. We have still to explain the parallel zones of high intensity. There is no explanation which we can advance with confidence, but at least one hypothesis does perhaps fit some of the facts. It is suggested that as a result of a general westerly movement of this part of the Peninsula the whole of the country north of an east-west line striking south of Allahabad and Dumka was in a state of strain before the earthquake. The strain reached a maximum along the Motihari-Purnea belt, north of which the movement was either *nil* or to the east. On fracturing along this belt the elastic rebound of the whole zone to the south was partly taken up by a sudden distortion or even occasional fracture in parallel belts (fig. 8). A slight variation of this view is the possibility that the alternating stresses caused by rapid oscillation of the crust during rebound would set up a parallel series of fracture zones each emanating from an irregular interface between rocks of markedly different elasticity—comparable to the so-called "fatigue cracks" in materials.

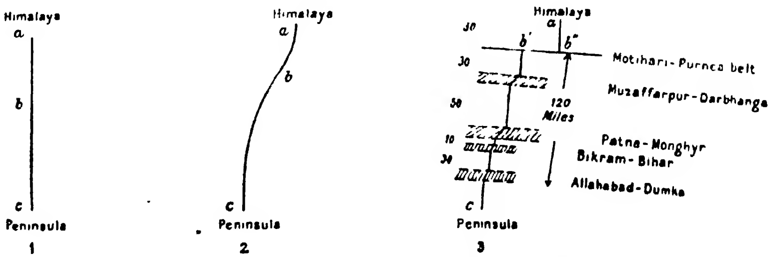

FIG. 8.—Development of parallel stress zones, Bihar-Nepal earthquake.

Lest it be inferred that such parallel movements should be apparent in seismograms to the south, as an earlier phase to the main pulse, it has been pointed out elsewhere (p. 83) that these secondary movements cannot take place sooner than the time taken for shear waves from the main focus to reach these belts. As the shear waves travel more slowly than P waves the seismic waves from the subsidiary movements must remain incorporated in the general seismogram of the main shock.

In this discussion of the significant trend of the isoseismals and of the belts of higher intensity we have ignored wave interference as a possible explanation. Of the principal destructive vibrations east-west oscillating shear waves were the dominant components, north-south condensation-compression components having little effect. We see no way in which there could have been such amazingly regular reinforcements of the shear waves as to give rise to these belts of higher intensity, except by further actual shearing.

We put forward our suggestion with some diffidence: it is perhaps the natural view of the geologist and possibly ignores certain properties of seismic waves with which we are unfamiliar.

The width of the strain zone (100 miles) postulated south of the actual fracture is perhaps greater than most geologists would admit. For the San Francisco earthquake Reid has remarked that the strain zone could not have been more than 56 miles in width, and that measurable movement was limited to a belt less than 6 miles in width (1935, p. 95). We admit the difficulties, but would point out that we have here in Bihar a region of massive gneissic rocks of great thickness, and the elasticity of which would be greater than that of younger bedded rocks.

Time of the earthquake.

The time of origin of the earthquake as interpreted from the seismograms has been already discussed by Dr. Roy. He has concluded that the first preliminary tremors began at 8 h. 43 m. 21 s. G. M. T. or 14 h. 13 m. 21 s. I. S. T. In our preliminary account of the earthquake (Auden and Ghosh, 1934, p. 213) the time of origin was considered to be 14 h. 13 m. 15 s, I. S. T., a figure which was based on a less detailed analysis of the seismograms.

It is interesting to note the accuracy of local records as compared with those of the seismograph stations. As was the experience

in previous earthquakes, no reliance can be placed on the majority of time estimates made in the earthquake area. In spite of the fact that railway stations and telegraph offices are supposed to receive Indian Standard time every day, estimates given by the observers varied greatly. In Bettiah, the Postmaster gave the time as 14-05 while the Station Master stated it was 14-15. An accurate clock belonging to Mr. Elms, Manager of the Bettiah Raj, stopped at 14-12. Mr. Kilburne, of Katmandu, gave the same time—14-12. His watch is checked daily by wireless. The clock of the Muzaffarpur Telegraph Office stopped at 14-15. That in the tower of the Secretariat building at Patna stopped at 14-16, evidently some time after the earthquake began.

Duration of the shock.

Within the area over which the shock was felt severely the times given for the duration of the shock vary considerably from 2½ to 5 minutes. Taking into account the actions of many people and the distances they moved during the shock and the experiences they underwent the period of 5 minutes can be quite readily accepted.

Most observers noticed more than one shock, the majority reported two. No clear distinction in the duration or number of felt shocks could be made out for different parts of the area of higher intensity.

The great duration of the shock must be attributed largely to the length of the fracture. The fact that the greatest damage did not take place until the lapse of over two minutes may also be attributable to the same reason. As Reid has pointed out, at the time of intitial rupture the rigidity of the rock would prevent large movements of the two sides of the fracture, but as this increased in size the movements would become greater, giving rise to the severest moments of the shock. One might compare this view with Dr. Roy's interpretation of an early movement emanating from lat. 26° 18′ long. 86° 18′ with, 11 seconds later, a movement of greater intensity further W. N. W. at lat. 26° 21′ long. 86° 12′. Reid (1933, p. 99) also remarks that the " friction at the fault would make these movements irregular, so that the vibrations sent out would not be a steady, strong series, but would vary so much in intensity

that they would produce the effect of strong shocks separated by weaker intervals." The duration of the severest part of the shock at any one place is also partly due to the length of time taken by the vibrations to arrive from distant parts of the fracture. It should be remembered that the fracture itself cannot extend faster than the fastest or compressional seismic waves and probably lags somewhat behind. If then, the fracture started near Madhubani and the first compressional waves took *a* second to reach, say, Sitamarhi, the vibrations from the fracture at Sitamarhi would not be felt back at Madhubani until at least *2a* seconds later. The time might well be *3a* seconds, for in the more distant parts to which the fracture extends the strain will be at first much below the breaking limit and time will be required for the elastic stresses at any point to build up to the breaking limit.

We have not been able to note any consistent variation in the felt duration of the shock from point to point in the epicentral region, as recorded by local people. It is unfortunate that more particular attention was not paid to this aspect of the shock, as a closer comparative study of its duration may have thrown some light on the direction of spread of the fracture, independently of the evidence provided by Dr. Roy.

We have already pointed out the probability that the elastic strain from which the earthquake originated occupied not a mere plane but a large volume of the crust, extending perhaps as far as 100 miles out from and parallel to the eventual fracture. It should not be inferred from this that the vibrations at any distant point within the strained area should be felt before the arrival of the elastic waves emanating from the fracture itself. The shear strain is first relieved by rebound along the sides of the fracture, these rebounds, of gradually diminishing amount, are transferred outwards from the fracture, but at a speed not greater than the shear waves set up at the fracture itself. Hence, even at a distant station far beyond the strain zone, the vibrations emanating from any near part of that zone cannot arrive before the vibrations set up at the initial point of fracture. The compression or P waves from any point of the strain zone will necessarily lag far behind those from the original point of fracture, as the shear waves which gave rise to rebound at such point within the strain zone move more slowly than the compression or P waves from the original point of fracture.

Intensity.

An approximate idea of the horizontal component of acceleration is obtained from measurements of fallen objects using West's formula :—

$$f = \frac{g\,x}{y}$$

It is usually impossible to state whether or not the fallen objects had swayed prior to falling. Eye witnesses frequently noticed the sway of objects and it is certain that some of the pillars and gate posts did so as well. The most serious likely source of error is that objects, such as gate posts, often move laterally on their base before falling so that their hinge point is often not the outer edge and the value of x is therefore often smaller than the measurement usually

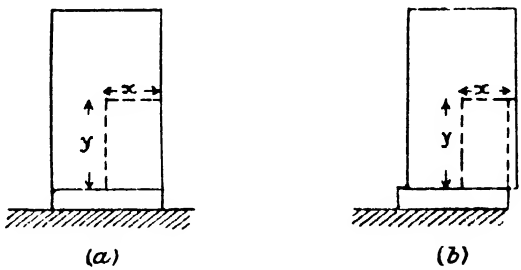

FIG. 9.—Reduction of x where pillars shifted laterally before toppling.

taken, as in fig. 9. Hence calculated values for acceleration may be sometimes in excess of the actual values. Measurements were taken only of objects that had fallen from their base. The calculated values for acceleration are given below :—

Monghyr	3,270 mm. per sec. per sec.
Sitamarhi	3,000 ,,
Muzaffarpur	3,050 to 2,647 ,,
Pipra	2,943 ,,
Rampur Hari	2,400 ,,
Katmandu	2,048 ,,
Pusa	1,500 ,,

Of these values that for Monghyr was calculated from the measurements of a gatepost which could not possibly have moved laterally before overturning, as the shape of the fracture at the base was such as to prevent it.

It is remarkable that the shock in Nepal failed to overturn many of the stone columns supporting images (Plate 25, fig. 2). These columns were cut from single blocks of stone, and were presumably deeply set into the ground. If not deeply set, the centroid of gravity would have been high, and the columns would inevitably have fallen. Some of the overlying capitals did fall, such as that in Hanuman Dhoka at Katmandu, and these were found to have deep tightly-fitting sockets. Good craftmanship, good rock and deep setting were evidently responsible for the frequent escape of these structures.

The amplitude of vibration was determined by the use of the formula :—

$$2a=\frac{4x(x^2+y^2)}{3y^2}$$

and gives figures ranging from 30·8 cms. or 12 inches at Muzaffarpur to 13·31 cms. or 5·2 inches at Katmandu. The range, or double amplitude, will be respectively two feet and 10·4 inches.

Railway sleepers along a line orientated north-south near Motihari had pushed the ballast into piles, leaving gaps varying from 8 to 12 inches in width. If these figures are an indication of the true double amplitude, it is possible that the figures obtained by the use of the above formula for amplitudes in the Muzaffarpur-Champaran area may be too large. Near Udaipur Garhi, in Nepal, a stone was dislodged from its position on soil by nine inches. The amplitude would then be $4\frac{1}{2}$ inches. However, the reliability of measurements provided by such sleepers and stones, whose lateral movement is likely to increase with every vibration, is very doubtful.

The period of vibration was determined by the use of the formula for simple harmonic motion :—

$$f=\frac{4\pi^2 a}{t^2}$$

This varied from just below two seconds to $1\frac{1}{2}$ seconds. As the motion was certainly not simple harmonic, the values of these figures are probably not very accurate.

In the Preliminary Report Dr. Coulson was quoted as having determined for Calcutta (isoseismal VI) the value of the acceleration (150 mm. per sec. per sec.), amplitude (15 mm.) and period (3 secs.) from measurements of the displacement of the horizontal pendulum

of the seismograph in Calcutta. This quotation is incorrect as the acceleration was merely calculated from an *assumed* amplitude of 15 mm. and period of 3 secs. (giving an acceleration of 70 mm. per sec. per sec.), and not from measurements of the seismograph records which were incomplete. Dr. Coulson thought that the acceleration would actually be nearer to 150 mm. per sec. per sec. in which case the values for amplitude and acceleration would also be correspondingly different. It is very likely that the acceleration in Calcutta actually reached 250 mm. per sec. per sec.

There is unfortunately very little evidence as to the extent of the vertical component of the earthquake waves. The thuds that were felt throughout the badly affected area certainly indicate that this was considerable. One observer at Monghyr stated that he saw a house lifted vertically, and then sink and shatter. In places the vertical acceleration must certainly have exceeded that of gravity.

Direction of fall and movement.

On Plate 4, is shown the directions of fall of pillars, chimneys, water tanks, etc., and movement of hanging objects. An arrow is given where the directions of fall are mainly to one point of the compass; when equally to two opposite points, a line is shown.

A large proportion of buildings and structures in Bihar and Nepal are orientated north-south. A pillar so orientated will fall to one of the cardinal points, since it would not fall diagonally. A single movement of the ground in, say, a N.W.—S.E. direction would act diagonally, and its forces would be resolved in east-west and north-south directions. This possibility should be allowed for. In the case of round chimneys, there is no such uncertainty. At Katmandu, observers stated that distinct shocks in east-west and north-south directions were felt, so that it is probable that the directions of fall do not represent resolved parts, but are a true indication of the movements. The same remarks apply to the swing of hanging objects such as lights and punkahs, for the alignment of the building and of roof and ceiling beams would have some influence on the swing of objects suspended from them, particularly if the building is not completely rigid.

In contrast to many earthquakes which show a centripetal distribution of directions of fall, in the present earthquake there

was a regional east-west direction, except in the west of the epicentral and neighbouring region. Between Hajipur and Sitamarhi the fall is fairly exactly to N. N. E. or S. S. W. It is E. N. E. at Pipra and Udaipur Garhi. At Katmandu it was to east or west and to north or south. Except for the north front of Patna, near the bank of the Ganges, every place south of the Ganges reported east-west movements even as far south as Ganjam in Orissa. There is no sign anywhere of a consistent centripetal disposition towards a point, or even an area.

One notable exception to the east-west movement is Calcutta, where the direction was consistently more nearly north and south. A possible explanation of anomalies is the type of wave dominant at a particular point. South from the epicentral tract the more rigid Peninsular rocks are quickly entered and the east-west oscillating shear waves would tend to remain dominant. Owing to the great length of alluvium north of Calcutta these east-west oscillating shear waves would tend to be damped out in the loose alluvium before reaching Calcutta, and the principal component of the pulse may well be a north-south compression-condensation movement.

CHAPTER VI.

ACCESSORY SHOCKS—THEIR SIGNIFICANCE.

(D. N. WADIA.)

Foreshocks.

Most earthquakes of tectonic origin are accompanied by accessory shocks. Shocks of any magnitude are usually heralded by some premonitory tremors (foreshocks), whilst almost every severe earthquake is followed by several hundred and even thousands of minor shocks (aftershocks), which steadily decrease in intensity, with slight fluctuations, and which continue for weeks, months and sometimes years. In an area unprovided with seismographs, such as Bihar, the foreshocks or other disturbances may be quite unheeded if they are of an intensity less than V or IV. In Japan, where seismographic registration has been systematically developed, the foreshocks, especially when accompanied by slight but prolonged tilting of the ground, are now used as the basis of a system for predicting the destructive earthquakes which are believed to follow such symptoms. This ground tilt, as a precursor of violent seismic disturbance, is measured by a delicate type of recording clinometer or tilt-measurer (Imamura, 1930). The subject, however, is still a matter of research and the accumulated precise data are as yet insufficient to be of practical importance.

Both the foreshocks and aftershocks are usually most prevalent in and more or less confined to the epicentral region of the principal quake and in most cases cluster round the central tract enclosed within the isoseismal of high intensity.

There is no recorded proof or reliable information of foreshocks having been felt in the region surrounding North Bihar prior to the main shock of 15th January 1934. Mention may be made, however, of a number of shocks which were felt on the 11th, 12th and 13th of January in some parts of South India, *e.g.*, Tinnevelli, Polachi, Sivakusi and several localities in the Anaimalai hills. On two different occasions earlier in the month a resident of Puri felt slight movement of the ground and vibrations 'exactly the same as those experienced on the 15th instant'; soon after the shock a distinct

rumbling noise was heard. There is no justification for connecting these distant shocks with the great Bihar earthquake.[1]

Aftershocks.

In marked contrast with the absence of foreshocks is the number of aftershocks which succeeded the great earthquake of Bihar. A total of several hundred aftershocks has been recorded, but it is certain that a much larger number of less intense shocks was not observed or listed. In spite of this fact the seismic activity had not completely disappeared even after a lapse of twenty months, although it was greatly diminished; but seismic activity had all but ceased at the close of 1935 and at the time of writing (November 1936) there is no perceptible sign of the continuation of the Bihar earthquake.

Several smart shocks were felt in rapid succession throughout the whole epicentral area during the first two days following the main shock; later, aftershocks rapidly decreased in frequency, although scarcely in intensity, during the first month. The intensity of these shocks was marked by many intermittent fluctuations. Several irregularly recurring maxima and minima can be discerned, even at the end of a year, at those centres from which there has been anything like a continuous record.

Table 9 gives the available data of the reported aftershocks from the epicentral area enclosed within isoseismal VIII and its immediate neighbourhood. The list includes only those shocks which were strong enough to be felt by most residents and were subsequently reported in the newspapers; it should be regarded as a statement of the more important aftershocks and nothing more. In addition, as not even a single seismograph existed in the shaken country, this list of individually recorded shocks suffers from a lack of continuous or systematic observation. Notwithstanding that the Geological Survey circulated instructions regarding the urgency and importance of carefully recording these later shocks in as many centres as possible, and that the officers who toured the damaged areas also conveyed verbal advice on this matter to the local authorities. no

[1] See p. 381 of Pt. II, of this Memoir.

[2] We make grateful acknowledgment to S. Khuda Buksh, Esq., Indian Police (Retired) of Patna, for use of his carefully compiled list of newspaper reports of earth tremors felt in Bihar after 15th January 1934 and continued to February 1936.

systematic day to day record has been kept by any Government department or private agency in the region. The list, although obviously incomplete, is the best that can be arranged. At many places several severe aftershocks have not been recorded whilst less intense shocks have been noted with some regularity; from other important places within the central seismic area, such as Nepal, Monghyr and Purnea, records giving even approximate data have not been received.

Following the Assam earthquake (1897), Kangra (1905) and some smaller Indian earthquakes, the Geological Survey investigations were materially assisted by local groups of people who, at a number of centres, systematically compiled details of subsequent shocks and tremors.

Although the imperfections of Table 9 must be acknowledged, it is nevertheless capable of furnishing some useful information, as will be seen later.

Tables 10, 11 and 12 give the seismographic records of the aftershocks which were registered at the Observatories of Alipore (Calcutta), Agra and Colaba (Bombay).

TABLE 9.*

More perceptible aftershocks, reported mainly in the newspapers.

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	January 15 to January 25.	..	..	*Siliguri.*—Almost daily.
„	15th January . .	About 17 00 and 21 00	.. ..	*Siliguri.*— Two shocks. 7 or 8 shocks at night.
„	15-20th „ . .	..	..	*Katmandu.*— *Patan.*— *Bhatgaon.*— 28 shocks in six days. No considerable damage.
„	15th January . .	19 30	..	*Hajipur.*—One shock.
„	„ . .	19 30	..	*Warisnagar, Darbhanga district.*—One shock
„	„ . .	20 00	..	*Muzaffarpur.*
„	„ . .	20 30	A few seconds.	*Bagdogra, Darjeeling district.*—One shock.
„	„ . .	21 00	..	*Motihari.*—One shock.
„	„ .	22 30	..	*Muzaffarpur.*—Shrieking and howling of panic-stricken mob in bazaar.

* Kindly compiled by Mr. A. B. Dutt.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	15th January . .	23 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
"	" . .	Night	..	*Sitamarhi.*—Shocks felt 10 times.
"	16th January . .	00 00 midnight.	..	*Motihari.*—One shock.
"	" . .	00 00 midnight.	..	*Muzaffarpur.*—One shock.
"	" . .	0 20	15	*Gorakhpur.*—Perceptible shock.
"	" . .	00 30	..	*Hajipur.*—One shock.
"	" . .	1 15	..	*Muzaffarpur.*—One shock.
"	" . .	1 20	A few seconds.	*Bhagalpur.*—One shock ; no damage.
"	" . .	1 30	3 to 5	*Pusa.*—Tremors
"	" . .	1 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
"	" . .	2 00	..	*Darbhanga.*—One shock.
"	" . .	2 30	..	*Muzaffarpur.*—One shock.
"	" . .	3 15	..	*Muzaffarpur.*—One shock.
"	" . .	4 00	..	*Pusa*.—One shock ; beds were rocking
"	" . .	4 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
"	" . .	5 00	..	*Motihari.*—One shock.
"	" . .	5 30	..	*Hajipur.*—One shock.
"	" . .	6 00	..	*Muzaffarpur.*—One shock.
"	" . .	6 00	..	*Pusa.*—Rumbling noise.
"	" . .	6 00	..	*Pusa*.—One tremor with rumbling sound.
"	" . .	6 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
"	" . .	8 00	..	*Muzaffarpur.*
"	" . .	10 00	..	*Muzaffarpur.*—One shock.
"	" . .	10 00	60	*Jamui.*
"	" . .	10 00	60	*Gawan.*
"	" . .	10 19	..	*Motihari.*—One shock.
"	" . .	10 20	..	*Buxar.*—One feeble shock.
"	" . .	10 25	6	*Pusa.*—One moderate shock with up and down movements.
"	" . .	10 30	..	*Bihar.*—Strong shock
"	" . .	10 30	A few seconds.	*Bhagalpur.*—One shock ; no damage.
"	" . .	10 30	..	*Darbhanga.*—One shock.
"	" . .	10 30	..	*Rushera Ghat.*—One shock.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	16th January . .	About 10 30	About 5 seconds.	*Gopalganj, Saran district.*—One shock.
"	" . .	10 30	..	*Hajipur.*—One shock.
"	" . .	10 30	2-3 secs.	*Patna.*—Mild shock.
"	" . .	10 30	60	*Motihari.*—One shock.
"	" . .	10 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*—Quite large shock; rattling factory.
"	" . .	10 30	..	*Muzaffarpur.*—One shock.
"	" . .	10 30	60	*Champaran.*
"	" . .	10 30	60	*Sonepur.*
"	" . .	About 10 30	..	*Siwan, Saran district.*—A slight tremor.
"	" . .	10 40	..	*Dhanbad.*—One tremor.
"	" . .	..	..	*Dalsing Sarai.*—Smart shock.
"	" . .	11 00	..	*Darbhanga.*—One shock.
"	" .	11 00	..	*Ballipur.*—Moderate shock; rumbling noise.
"	" . .	..	..	*Sitamarhi.*—3 or 4 shocks during the day. Direction of shock from N. W.
"	" . .	Noon.	..	*Patna.*—One severe shock.
"	" . .	Noon	..	*Madhepore, Darbhanga district.*—Three minor shocks.
"	" . .	14 00?	..	*Muzaffarpur.*
"	" . .	14 17	..	*Sonepur.*—Smart shock.
"	" . .	20 00	5	*Khoribari, Darjeeling district.*—One moderate shock.
"	" . .	Between 20 00 and 21 00	..	*Patna.*—Mild shock.
,	" . .	About 22 00	..	*Gopalganj, Saran district.*—One slight shock.
"	" . .	22 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
"	" .	About 22 30	..	*Siwan (Chapra).*—One shock.
"	" . .	Night	..	*Sitamarhi.*—Shocks felt 5 times.
"	" . .	Night	..	*Warisnagar, Darbhanga district.*—Some 4 to 6 shocks.
"	" .	Not known.	..	*Bagdogra, Darjeeling district.*—One slight shock.
"	17th January .	Between 2 00 and 4 00	..	*Patna.*—Two slight shocks.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.). H. M.	Duration of shocks (in seconds).	Station and descriptive details.
1934	17th January .	2 00	..	*Kurseong.*
,,	,, . .	2 30	..	*Motipur, 17 m. N. W. of Mazaffarpur.*
,,	,, .	8 30	..	
,,	,, . .	12 05	..	*Motihari.*—One mild shock.
,,	,, . .	12 20	30	*Jamui.*—One shock.
,,	,, . .	15 00	..	*Ballipur (Tirhut district).*— Slight tremors.
,,	,, .	16 00	..	*Hajipur.*—One shock.
,,	,, . .	21 00	2	*Mungpo, Darjeeling district.*—One rather strong shock.
,,	,, . .	Night	..	*Sitamarhi.*—Shocks felt 3 times.
,,	,, . .	Night	..	*Muzaffarpur.*—Three shocks.
,,	,, . .	..	..	*Laukaha, Darbhanga district.*—One shock.
,,	18th January . .	Midnight 00 00	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
,,	,, . .	00 05	60	*Jamui.*—Shocks lasting 60 secs.
,,	,, . .	00 05	About 8 secs.	*Khoribari, Darjeeling district.*—Two or more strong shocks.
,,	,, . .	00 20	30	*Gorakhpur.*—Smart shock, doors and windows rattled.
,,	,, . .	2 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
,,	,, . .	..	..	*Laukaha, Darbhanga district.*— One shock.
,,	19th January .	00 00	60	*Sitamarhi.*—Smart shocks: Motihari, 60 secs., Satgawan, 120 secs.
,,	,, . .	00 00	30	*Gorakhpur.*—Moderate shock
,,	,, . .	00 12	30	*Giridih.*- One shock, 60 secs.
,,	,, . .	00 15	120	*Palamau.*—120 secs.
,,	,, . .	00 20	40	*Chatra.*—One shock.
,,	,, .	00 21	..	*Motihari.*— One shock.
,,	,, . .	00 30	45 to 60	*Deoghar.*—One shock of moderate intensity.
,,	,, .	00 30	30	*Pakur.*— One shock.
,,	,, . .	1 00	..	*Mohiuddinagar, Darbhanga district.*--One shock.
,,	,, . .	1 20	..	*Darbhanga.*- One shock.
,,	,, .	4 05	About 6 secs.	*Khoribari, Darjeeling district.*—Two rather strong shocks.
,,	,, .	16 00	½ a sec.	*Mungpo, Darjeeling district.*—One shock; not strong.
,,	,, . .	Night	..	*Sitamarhi.*—One shock.
		Night	120	*Gawan.*—Tremors.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	19th January . .	..	..	*Laukaha, Darbhanga district.*—One shock.
,,	19/20th January . .	Night	..	*Khagoul, Patna.*—One shock the effect of which was to enlarge the previous cracks; no other damage.
,,	20th January . .	00 00 midnight.	Not over 15 secs.	*Motihari.*—One shock.
,,	,, . .	00 00 midnight.	Very short.	*Nawada, Gaya district.*—One shock of very slight intensity.
,,	,, . .	00 05	..	*Chapra Kachari Railway Station.*—One shock.
,,	. .	00 08 to 00 12	60	*Daltonganj.*—One strong shock accompanied by buzzing sounds.
,,	,, . .	00 10	..	*Samastipur.*—One smart shock.
,,	,, . .	00 12	180	*Hazaribagh.*—Several shocks in quick succession; another shock after 10 minutes.
,,	,, . .	00 15	15	*Daltonganj.*—Smart shock.
,,	,, . .	00 15	120	*Dhanbad.*—Severe tremors.
,,	,, . .	00 16	8 to 10 seconds.	*Pusa.*—One shock rousing people from sleep; movement from north to south.
,,	,, . .	00 16	59	*Jalpaiguri.*
,,	,, . .	00 18	About 60 secs.	*Kishanganj, Purnea district.*
,,	,, . .	00 20	About 40 secs.	*Darjeeling.*—One shock of slight severity; no damage.
,,	,, . .	00 20	60	*Pratabpur.*
,,	,, . .	00 20	..	*Muzaffarpur.*—One shock.
,,	,, . .	00 22	30	*Marhaurah.*—Tremors accompanied by feeble noise.
,,	,, . .	00 23	2 or 3	*Muzaffarpur.*—One slight shock; no casualties but the shock caused damage to buildings.
,,	,, . .	00 23	A few seconds.	*Nayagoan (Sonepur).*—Strong tremors.
,,	,, . .	00 25	A few seconds.	*Bhagalpur.*—One mild shock; no damage.
				Bihar.—One strong shock.
,,	,, . .	00 25	40	*Gonda.*—Three mild shocks.
,,	,, . .	00 30	..	*Buxar.*—One shock.
,,	,, . .	00 30	60	*Champaran.*
,,	,, .	00 30	60	*Dumri.*
,,	,, . .	00 30	..	*Deoghar.*—One sharp shock.
,,	,, . .	00 30	30	*Pakaur.*—One shock.
,,	,, . .	00 30	30	*Motipur.*—One shock.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	20th January . .	00 30	..	*Hajipur.*—One shock.
,,	,, . .	00 30	..	*Motipur.*—Big shock.
,,	,, . .	00 30	60	*Palamau.*—Several tremors.
,,	,, . .	00 40	8	*Patna.*—The shock reawakened the city ; no casualties but many buildings which had been damaged, collapsed. Direction N-S.
,,	,, . .	00 45	120	*Motihari.*
,,	,, . .	01 30	..	*Kathmandu* (*Nepal*).—One perceptible shock.
,,	,, . .	4 00	..	*Motipur.*
,,	,, . .	Early hours of the morning.	..	*Madhupur.*—One sharp shock lasting about a minute.
,,	,, .	5 30 9 45	.. ..	*Motipur.*—Moderate shocks.
,,	,, . .	12 30	..	*Darbhanga.*—One shock.
,,	,, . .	..	.	*Laukaha, Darbhanga district.*—One shock.
,,	21st January . .	00 20	60	*Karmatar.*
,,	,, . .	00 30	..	*Motipur.*
,,	,, . .	About 00 30	..	*Berhampore.*—One slight shock.
,,	,, . .	13 00	..	*Madhepore, Darbhanga district.*—One shock
,,	,, . .	22 00	..	*Buxar.*—One shock.
,,	,, . .	Night	..	*Sitamarhi.*—Shocks felt twice.
,,	22nd January . .	Midnight 00 00	..	*Motipur, 17 m. N. W. of Muzaffarpur.*
,,	,, . .	1 21	..	*Pusa.*—Moderate shock, Ligh tremors could be felt at times up to the 27th January, 1934.
,,	,, . .	1 25	..	*Motipur.*
,,	,, . .	1 30	..	*Muzaffarpur.*—One slight shock.
,,	,, . .	..	..	*Muzaffarpur.*—Two shocks.
,,	23rd January . .	6 30	..	*Madhepore, Darbhanga district.*—One minor shock.
,,	24th January . .	00 45 1 00 2 00 15 00 17 00 21 30	..	*Motipur, 17 m. N. W. of Muzaffarpur.*—Rather large shock at 21-30 hours.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.). H. M.	Duration of shocks (in seconds).	Station and descriptive details.
1938	25th January . .	9 00	..	*Between Barh and Pandarak (Near Patna).*—Great sounds undergound followed by a momentary vibration.
,,	,, . .	Night	..	*Sitamarhi.*—One shock.
,,	26th January . .	Night	..	*Sitamarhi.*—Shock felt once.
,,	27th ,, . .	16 30	..	*Purnea.*
,,	28th ,, . .	1 00	..	*Motipur.*—Large shock at 1·00 hour; everyone rushed out.
,,	,, . .	8 00	..	*Muzaffarpur.*
,,	,, . .	15 00	..	} *Motipur.*
,,	,, . .	22 00	..	
,,	,, . .	Night	..	*Laukaha, Darbhanga district.*—One shock.
,,	,, . .	Night	..	*Sitamarhi.*—Shocks felt thrice.
,,	29th January .	..	..	*Chapra.*—One smart shock.
,,	,, . .	1 00	..	*Darbhanga.*—One shock.
,,	,, . .	5 30	..	*Motipur.*—Roof rattled.
,,	30th January . .	Night	..	*Sitamarhi.*—Shock felt once.
,,	,, . .	22 00	..	*Motipur.*
,,	,, . .	..	..	*Muzaffarpur.*—One shock.
,,	31st January . .	6 15	..	*Motipur.*
,,	,, . .	Night	..	*Laukaha, Darbhanga district.*—One shock.
,,	31st(?) ,, . .	Night	..	*Muzaffarpur.*—One slight shock.
,,	1st February . .	18 30	..	*Jale, Darbhanga district.*—One shock.
,,	2nd ,, . .	21 50	..	} *Motipur.*
,,	3rd ,, . .	21 45	..	
,,	,, . .	23 30	180	*Khepupara, Bakarganj district.*—Mild shocks.
,,	4th February . .	2 25	..	*Muzaffarpur.*—One shock.
,,	,, .	Night	..	*Sitamarhi.*—Shock felt once.
,,	5th February . .	2 10	..	*Darbhanga.*—One shock.
,,	,, . .	2 20	..	*Muzaffarpur.*—One shock.
,,	,, . .	2 19	..	*Pusa.*—One slight shock.
,,	,, . .	2 20	..	*Muzaffarpur.*—Shock lasted a few seconds.
,,	,, . .	Night	..	*Sitamarhi.*—Shock felt once.
,,	,, . .	15 50	..	*Muzaffarpur.*—One shock.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	8th February . .	8 30	..	*Araria, Purnea district.*—One shock.
"	" . .	20 00	1½	*Naya Dumka.*—One rather strong shock.
"	" . .	Night	..	*Raxaul.*—Severe tremors.
"	10th February . .	20 23	..	*Pusa.*—Slight shock.
"	" . .	Evening	..	*Darbhanga.*—Shook punkhas; new cracks developed.
"	11th February . .	09 45	..	*Araria, Purnea district.*—One shock.
"	" .	10 15 to 10 30	..	*Darbhanga.*
"	" . .	20 23	..	*Motihari.*—One shock.
"	" . .	20 30	..	*Hajipur.*—One shock.
"	" . .	Night	..	*Muzaffarpur.*—One shock of moderate intensity.
"	" . .	Night	..	*Sitamarhi.*—Shock felt once.
"	" .	Night	..	*Raxaul.*—Further shocks were felt.
"	12th February .	8 30	..	*Motihari.*—One shock.
"	" . .	9 30	3	*Hajipur.*—One shock.
"	" . .	9 30	..	*Benipore.*—One severe shock.
"	" . .	About 9 30	..	*Muzaffarpur.*—One shock.
"	" . .	9 35	..	*Samastipur.*—One shock from northerly direction.
"	13th February . .	9 40	..	*Raxaul.*—One shock of moderate intensity.
"	" . .	23 02	..	*Darbhanga.*—One slight tremor (According to Mr. A. M. N. Ghosh).
"	. .	..	..	*Sitamarhi.*—One shock of severe intensity; a number of fissures appeared in the ground, from which water gushed out.
"	15th February . .	2 00	..	*Madhepore, Darbhanga.*—One minor shock.
"	" .	23 00	..	*Hajipur.*—One shock.
"	16th February . .	15 30	..	*Madhepore, Darbhanga.*—One ordinary shock.
"	17th February . .	6 00	..	*Madhepore, Darbhanga district.*—Another similar shock.
"	" . .	6 03	..	*Lohat, Darbhanga district.*—One shock.
"	" . .	8 00	..	*Kesariya, Motihari District.*—One shock.
"	" . .	8 30	..	*Motihari.*
"	" . .	8 30 to 9 00	..	*Lohat.*—One shock.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M		
1934	17th January to	7 00	..	*Madhepore, Darbhanga district.*—Two shocks.
,,	18th ,,	7 00	..	
,,		18 33	3 secs.	*Samastipur.*—Smart shock. Doors rattled. Direction N.-S.
,,	20th February	20 44	..	*Pusa.*—Tremors were felt.
,,	21st ,,	23 25	..	*Hajipur.*—One shock.
				Rushera Ghat.—Slight shock, accompanied by rumbling noise.
,,	22nd ,,	22 20	..	*Hajipur.*—One shock.
,,	23rd ,,	Night	..	*Sitamarhi.*—Shock felt once.
,,	25th ,,	1 30	..	*Sitamarhi* —Smart, shock, people awakened from sleep.
,,	2nd March	9 00	..	*Madhepore, Darbhanga district.*—One shock.
,,	,,	9 45	..	*Darbhanga.*
,,	,,	19 15	..	*Madhepore, Darbhanga district.*—One shock.
,,	5th March	..	..	*Darbhanga.*
,,	11th March	6 00	About 30 secs.	*Khoribari, Darjeeling district.*—Two or three shocks of moderate intensity; motion west to east.
,,	,,	6 03	15 secs.	*Nipania, Nepal.*—Earth tremor, rapid vertical vibrations and low rumbling sound. Dogs barked. No damage.
,,	9th April	2 00	Over 10 seconds.	*Muzaffarpur.*—One shock of moderate intensity preceded by a peculiar sound; no casualty.
,,	,,	2 20	A few seconds.	*Barh.*—One shock of slight intensity.
,,	,,	2 20	A few seconds.	*Darbhanga.*—Shock of mild intensity; no damage.
,,	,,	About 2 30	About 10 seconds.	*Bhagalpur.*—One shock of slight intensity.
,,	,,	About 3 00	..	*Sitamarhi.*—A severe shock.
,,	,,	Early morning.	..	*Raxaul.*—One shock of slight intensity.
,,	10th April	2 30	..	*Purnea* —One smart shock; heavy rain attended with storm was falling at the time; several buildings further sank by several inches.
,,	14th April	4 05 4 30	10	*Darbhanga.*—Two smart shocks, the second tremor was more severe than the first.
,,	,,	About 4 30	Very short duration.	*Darjeeling.*—One shock of slight intensity; no damage.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	14th April . .	..	..	*Jaipur* (*near Darjeeling ?*).—One shock.
,,	20th April	1 45 5 15	A few seconds.	*Darbhanga.*—Two shocks ; the second shock was followed by a loud rumbling sound ; no damage.
,,	25th ,, ...	Morning	..	*Madhubani* —Two more shocks preceded by usual rumbling sounds ; shocks not of much intensity.
,,	30th ,, ...	2 00 17 30	..	*Monghyr.*—Two more shocks ; the second shock was sharp though short
,,	8th May . . .	About 8 30	..	*Muzaffarpur.*—One shock ; a peculiar sound just preceded the shock.
,,	20th ,, ...	11 30	About 5 secs.	*North of Muzaffarpur district.*—One shock of moderate intensity.
,,	,, ...	11 30	..	*Sitamarhi.*—One shock.
,,	,, ...	10 40	A few seconds.	*Darbhanga.*—One rather strong shock.
,,	1st June . . .	12 00	?	*Bhagalpur.*
,,	,, ...	2 00	..	*Motihari.*
,,	,, ...	..	..	*Sitamarhi.*
,,	2nd June . . .	About 00 30	..	*Monghyr.*—One smart shock.
,,	,, ...	00 50	20	*Darbhanga.*—One shock of great intensity ; no considerable damage excepting slight cracks in the houses and the collapse of a few mud walls.
,,	, ...	1 00	..	*Chapra.*—One shock ; no report of any serious damage.
,,	,, . . .	1 00	About 5 secs.	*Muzaffarpur.*—One shock of considerable intensity ; a peculiar humming noise preceded the shock ; people became panic-stricken, left their beds and rushed to the open. An earthquake shock of considerable intensity was also felt in the interior of the district.
,,	,, ...	About 1 00	..	*Patna.*—One shock.
,,	,, ...	1 30	..	*Riga, near Sitamarhi.*—Moderate intensity.
,,	,, ...	About 2 00	..	*Purnea.*—One shock of moderate intensity ; no damage.
,,	,, ...	2 00 to 3 00	..	*Bhagalpur.*—Two shocks; first slight, second sharp though short.
,,	,, ...	4 00	.	*Riga* —Shock of moderate intensity.
,,	,, ...	11 20	2	*Naya Dumka.*—One shock.
,,	,, ...	11 30		*Monghyr.*—Two successive shocks, one of which was rather strong.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1934	2nd June	About 11 30	..	*Purnea.*—One shock of moderate intensity; no damage.
"	10th June	11 00	..	*Monghyr.*—One shock.
"	"	17 15	..	*Monghyr.*—One shock.
"	11th June	18 45	..	*Monghyr.*—One severe shock; several damaged walls collapsed.
"	17th "	2 10	About 20 secs.	*Siliguri.*—One shock of mild intensity; no damage to life and property reported.
"	18th "	About 17 00	A few seconds.	*Monghyr.*—One shock lasting a few seconds.
"	"	17 15	..	*Darbhanga.*—Two smart shocks in quick succession. The intensity of the shocks was severe. No damage reported.
"	"	17 20	..	*Muzaffarpur.*—One shock of considerable intensity; no damage.
"	"	17 30	..	*Barh.*—One shock of slight intensity.
"	19th June	Midnight	..	*Barh.*—Another slight shock.
"	"	5 20	..	*Muzaffarpur.*
"	"	..	..	*Baluha, Muzaffarpur.*—One slight shock; several walls in the village came down; no loss of life.
"	2nd July	1 40	About 10 secs.	*Siliguri.*—One shock of mild intensity; no damage reported.
"	15th July	7 34	30	*Siliguri.*—One shock of considerable intensity; no loss of life or damage to property.
"	"	17 45	A few secs.	*Darbhanga.*—One shock of considerable intensity.
"	"	Night	..	*Laukaha, Darbhanga district.*—One shock with rumbling noise.
"	23rd August	About 13 45	..	*Darjeeling.*—One slight shock.
"	24th "	12 00	..	*Warisnagar, Darbhanga district.*—One shock.
"	28th "	9 30	..	*Laukaha, Darbhanga district.*—One shock.
"	"	11 35	..	*Darbhanga.*—One shock.
"	29th "	9 00	..	*Madhepore, Darbhanga district.*—One severe shock.
"	"	9 10	Several secs.	*Muzaffarpur.*—One shock of considerable intensity; the inmates of all the houses rushed out for safety; no damage.
"	"	9 10	Short duration.	*Sonepur Junction.*—One shock of considerable intensity; no damage.
"	"	9 13	A few secs.	*Patna.*—One smart shock lasted a few seconds only.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.). H. M.	Duration of shocks (in seconds).	Station and descriptive details.
1934	29th August . .	9 15	About 2 secs.	*Darbhanga.*—One shock of high intensity; visible cracks appeared on a good many buildings and some houses fell.
"	" . .	9 30	..	*Gaya.*—One mild shock.
"	" . .	9 30	..	*Jalpaiguri.*—One shock of moderate intensity.
"	" . .	9 30	About 40 secs.	*Sitamarhi.*—A very sharp earth tremor; no casualty.
"	30th August . .	17 45	..	*Muzaffarpur.*—One slight shock.
"	23rd September . .	14 45	..	*Darjeeling and several North Bihar stations.*
"	14th December* . .	10 30	..	*Madhepore, Darbhanga.*—One shock with rumbling noise.
"	16th " . .	About 7 30	..	*Raxaul.*—One slight shock.
"	18th "	4 00	A few secs.	*Bhagalpur.*—One slight shock; no injury or damage.
"	" . .	4 45	2	*Muzaffarpur.*—One shock of slight intensity.
1935	10th January . .	4 39	..	*Chinsurah.*—One slight shock.
"	21st March . . .	5 20	About 20 secs.	*Naya Dumka.*—One rather strong shock accompanied by sounds like that of a motor car in motion.
"	"	5 34	..	*Calcutta.*—A series of earthquake shocks continuous for several minutes; the first shocks were of considerable intensity but became progressively slighter.
"	"	5 35	..	*Berhampore.*—Severe shock, rather strong.
"	" .	5 35	3 or 4 secs.	*Khulna.*—Three moderate shocks of which the middle one was the strongest.
"	"	..	..	*Chandernagore.*—Slight shock.
"	"	..	..	*Chinsurah.*—Slight shock.
"	" . . .	..	..	*Krishnagar.*—Moderate shock.
"	"	..	..	*Malda.*—Slight shock.
"	"	..	..	*Satkhira.*—Slight shock.
"	16th April . . .	7 00	..	*Darbhanga.*—One shock.
"	23rd April . . .	22 20	About 2 secs.	*Naya Dumka.*—One shock.
"	"	22 30	..	*Darjeeling.*—Two shocks.
"	"	..	..	*Berhampore.*
"	"	..	..	*Chinsurah.*

* This gap between September and December is due to non-record and not to any cessation of seismic activity.

TABLE 9—*contd.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1935	23rd April . .	..	..	*Krishnagar.*
"	"	..	..	*Satkhira.*
"	"	..	..	*Serampore.*
"	"	..	..	*Siliguri.*
"	30th June . . .	About 15 00	..	*Kalimpong.*—One slight shock ; no damage.
"	"	15 20	..	*Darjeeling.*—One shock lasted a few seconds.
"	"	About 15 35	Nearly 6 secs.	*Jalpaiguri*—One shock of moderate intensity.
"	1st July . . .	..	..	*Darjeeling.*—One slight shock.
"	4th "	..	..	*Dinajpur, Jalpaiguri and Darjeeling.*
"	24th August . .	About midnight	..	*Darbhanga.*—One severe shock
"	" . .	About midnight.	..	*Motihari.*—One severe shock.
"	" . .	About midnight.	..	*Muzaffarpur.*—One severe shock ; inhabitants rushed out of their houses ; no damage.
"	30th " . .	16 30	..	*Laukaha, Darbhanga district.*—One shock.
"	26th November . .	5 15	4	*Hazaribagh.*—One shock with a sound like that of a bus passing nearby.
"	" . .	5 22	20	*Ranchi.*—One sharp shock ; no damage.
"	" . .	5 24	..	*Hazaribagh.*—One shock of considerable intensity was felt accompanied by a rumbling sound.
"	8th December . .	22 36	..	*Siliguri.*—One slight shock for a few seconds; no damage.
"	12th " . .	20 00	..	*Sitamarhi.*—One sharp shock ; no damage.
"	21st " . .	9 30	..	*Laukaha, Darbhanga district.*—One shock.
1936	2nd January . .	4 20	About 30 secs.	*Siliguri.*—One shock of moderate intensity.
"	21st " . .	A little after 18 15	..	*Jalpaiguri.*—One moderate shock ; no damage.
"	27th " . .	16 00	..	*Purnea.*—One shock of moderate intensity.
"	" . .	About 16 00	1½	*Bhagalpur.*—One mild shock ; the wave of the tremor seemed to come from north-west.

TABLE 9—*concld.*

Year.	Date.	Time (I. S. T.).	Duration of shocks (in seconds).	Station and descriptive details.
		H. M.		
1936	11th February . .	About 10 10	..	*Purnea.*—One somewhat severe shock.
,,	,, . .	10 19?		*Bhagalpur.*—One shock.
,,	,, . .	10 19	..	*Calcutta.*—The shock was felt by some people.
,,	,, . .	10 19?		*Dholi, B. and N. W. Ry.*—The worst damage was reported from here; the station was damaged and a fissure appeared on the platform.
,,	,, . .	10 19?	3	*Muzaffarpur.*—One shock accompanied by a rumbling sound; no damage to buildings reported.
,,	,, . .	10 19?		*Patna.*—Tremors of moderate intensity.
,,	,, . .	10 22	3	*Katmandu.*—One sharp shock; no loss of life or heavy damage to property.
,,	,, . .	About 10 25	..	*Dumka.*—Three rather strong shocks with unusual sounds during them.
,,	,, . .	..	..	*Bhagalpur (Aligunj).*—Two persons died of injuries caused by a wall collapsing during a severe shock.
,,	,, . .	..	8	*Darjeeling.*—One shock lasting 4 seconds was followed by a more severe one of similar duration; no damage reported.
,,	12th February . .	2 00 to 3 00	..	*Jalpaiguri.*—Shocks were experienced.
,,	,, . .	2 30	..	*Bhagalpur.*—One shock.
,,	19th February . .	7 34	..	*Siliguri.*—One shock of moderate intensity lasting a few seconds; no damage.
,,	0th June . . .	About 5 34	..	*Bhagalpur.*—One sharp shock; no damage.
,,	,, . .	About 5 34	..	*Darjeeling.*—One sharp shock; no loss of life or damage to property.
,,	,, . .	About 5 34	..	*Gaya.*—One sharp shock; no damage.
,,	,, . .	About 5 34	..	*Muzaffarpur.*—One sharp shock; no loss of life or damage to property reported.
,,	,, . .	About 5 34	..	*Patna.*—One sharp shock; no loss of life or damage to property.
,,	,, . .	About 5 34	..	*Purnea.*—One sharp shock; no loss of life or damage to property.
,,	,, . .	About 5 34	..	*Siliguri.*—One sharp shock; no loss of life or damage to property, excepting slight damage to a private residence.
,,	,, . .	About 5 34	..	*Siwan, Saran district.*—One sharp shock; no damage or loss of life reported.

TABLE 10.

Aftershocks recorded at Alipore.

(In the case of many of the shocks mentioned in this statement, subsequent to March 1935, it is not definitely known whether they were of Bihar origin.)

Date.	Calcutta time of beginning of shock.	Epicentral distance (miles).	Intensity.	Remarks.
	H. M.			
1934				
January 15 . .	20 17	200	Tremor	
	20 48	200	,,	
	20 57	200	,,	
	21 14	200	,,	
	21 42	200	,,	
	23 16	200	,,	
	23 58	200	,,	
January 16 . .	01 43	200	,,	
	02 21	200	,,	
	02 24	200	,,	
	03 02	200	,,	
	03 28	200	,,	
	04 17	200	,,	
	08 54	200	,,	
	10 54	250	Moderate	Felt also in North Bihar.
	20 36	250	Tremor	
	21 58	200	Slight	
January 17 . .	08 39	200	Tremor	
	09 05	200	,,	
	09 43	200	,,	

TABLE 10—*contd.*

Date.	Calcutta time of beginning of shock.	Epicentral distance (miles).	Intensity.	Remarks.
1934	H. M.			
January 17 . .	09 47	200	Tremor	
	12 24	200	,,	
	13 00	200	,,	
	14 30	200	,,	
January 18 . .	00 30	200	,,	
	01 23	200	,,	
	02 39	200	,,	
	03 14	200	,,	
	03 57	200	,,	
	05 11	200	,,	
	10 41	200	,,	
	17 13	200	,,	
	19 05	200	,,	
	21 49	200	,,	
January 19 . .	18 50	296	Strong	
January 20 . .	00 44	250	Moderate	Felt in North Bihar.
January 21 . .	08 27	250	Slight	
	12 45	250	,,	
	20 52	250	,,	
January 22 . .	01 44	250	,,	
January 23 . .	11 19	250	,,	
January 24 . .	12 56	250	,,	
January 26 . .	05 53	250	,,	
January 31 . .	05 00	250	,,	
February 4 . .	18 44	250	,,	Felt in North Bihar.

TABLE 10—*contd.*

Date.	Calcutta time of beginning of shock.	Epicentral distance (miles).	Intensity.	Remarks.
1934	H. M.			
February 8 . .	20 35	250	Slight	
February 11 . .	20 47	300	,,	
February 12 . .	09 52	200	,,	
February 17 . .	08 45	400	,,	
February 18 . .	18 55	400	,,	
February 24 . .	21 18	300	,,	
March 26 . .	08 54	350	,,	
April 9 . . .	02 47	220	,,	
April 13 . . .	10 33	200	,,	
April 14 . . .	04 58	300	,,	
April 20 . . .	05 38	150	,,	
June 2 . . .	01 20	200	,,	
	11 49	400	Moderate	
June 17 . . .	02 07	250	Slight	
June 18 . . .	17 47	350	,,	Felt at Muzaffarpur, etc.
July 15 . . .	08 00	300	,,	
August 24 . .	13 07	330	,,	
August 29 . .	09 37	210	,,	Felt in North Bihar and Darjeeling.
September 23 . .	14 45	200	,,	
October 22 . .	01 03	300	,,	
	07 03	350	,,	
November 2 . .	21 14	350	,,	
November 3 . .	12 42	300	,,	
	19 27	300	Tremor	

TABLE 10—*concld.*

Date.	Calcutta time of beginning of shock.	Epicentral distance (miles).	Intensity.	Remarks.
1934	H. M.			
November 4 . .	08 05	300	Tremor	
November 23 . .	15 33	250	Slight	
December 18 . .	04 05	300	,,	
1935				
January 12 . .	03 10	..	Tremor	
	09 58	225	Slight	
March 4 . . .	22 12	330	,,	
March 21 . .	05 57	190	Tremor	Felt at Calcutta and at many places in Bengal.
April 18 . . .	20 54	350	Slight	
May 21 . . .	10 17	410	,,	
May 23 . . .	20 22	160	,,	
July 4 . . .	08 43	340	,,	Felt at Dinajpur, Darjeeling and in Bihar.
August 24 . .	00 29	280	,,	Felt in Bihar.
September 5 . .	18 30	310	,,	Felt in North Bengal.
October 26 . .	14 34	360	,,	
November 18 . .	00 09	380	,,	
November 26 . .	06 30	350	,,	

TABLE 11.

Aftershocks recorded at the Agra Observatory.

(This list includes all those shocks which have been considered as aftershocks of the Bihar earthquake, as judged from the distance of origin of the shocks and from the character of the records, the actual epicentres being undetermined at Agra.)

Date.	G. M. Time (Beginning of shock).	Epicentral distance in Kms.
	H. M.	
1934		
January 15	14 30	—
	14 54	845
	15 03	820
	15 21	810
	15 27	—
	15 47	845
	16 14	—
	16 20	—
	17 22	—
	18 04	820
	19 49	—
	20 27	810
	20 31	845
	21 08	—
	21 34	820
	22 23	—
	23 26	—
January 16	00 27	—
	02 00	—
	03 00	—

TABLE 11—*contd.*

Date.	G. M. Time (Beginning of shock).	Epicentral distance in Kms.
	H. M.	
1934		
January 16	03 19	820
	04 54	—
	05 00	810
January 17	06 33	790
	07 05	800
	18 37	820
January 19	18 51	830
January 21	06 53	780
February 2	19 51	—
	12 20	780
February 4	12 52	—
February 10	04 47	855
	22 57	780
February 12	03 58	900
February 17	02 53	855
April 8	20 54	—
April 13	23 05	855
August 29	03 44	755
December 17	23 14	—
1935		
April 16	00 43	—
August 23	18 37	845

TABLE 12.

Aftershocks recorded at the Colaba Observatory, Bombay.

(Only nine aftershocks were recorded at Colaba in 1934; none were registered in 1935.)

Date.	G. M. Time (Beginning of shock).	Period (Seconds).	Epicentral distance (Kms.).	Intensity.
	H. M.			
1934				
January 16 . .	05 02	3	1445	Slight.
19 . .	18 53	3	1611	Slight.
21 . .	06 56	—	—	Slight.
	19 55	—	—	Slight.
February 10 . .	04 50	—	—	Slight.
12 . .	04 00	—	—	Slight.
April 8 . . .	20 59	—	—	Feeble.
13 . . .	22 45	—	—	Very feeble.
August 29 . .	03 48	2	—	Feeble. Beginning doubtful.

In view of the paucity of local information an attempt was made to compile a list of aftershocks in Bihar and their epicentres from the instrumental data of the seismographic stations at Bombay, Agra, Dehra Dun and Calcutta. Information was sought from these records as to which parts of Bihar were more affected than others by aftershocks, and whether such shocks occurred in clusters. After discussion with Dr. S. K. Banerjee and Dr. S. C. Roy it was found that no such information was deducible from the available seismographic records, because the various components of only two of the aftershocks have been fully recorded; the seismological data is incomplete for the remainder.

Discussion.

Examination of the original seismographs from the Bombay, Agra and Alipore Observatories by Dr. Roy and the present writer shows that essential data for fixing the epicentres even approximately are lacking. In some cases the direction of the shock is not established with certainty and it is doubtful if some of those listed in the tables originated in Bihar. On examination of Tables 11 and 12 some coincidence between the aftershocks, grouped below, and recorded at Agra and Colaba, is apparent, and one would imagine it possible to locate their approximate epicentres in Bihar :—

Date.	Agra Observatory.	Colaba Observatory.	
January 16th . . .	5·00	5·02	
19th . . .	18·51	18·53	
21st . . .	6·53	6·56	
21st . . .	19·51	19·55	
February 10th . . .	4·47	4·50	
12th . . .	3·58	4·00	
April 8th . . .	20·54	20·59	
13th . . .	23·03	22·45	Very imperfect.
August 29th . . .	3·44	3·48	

Neither the Alipore nor the Dehra Dun seismographs, however, have recorded any of these shocks and one or two observed at Dehra Dun on these dates are not found in the above lists. Some of the records, moreover, are very incomplete and afford no data for calculating the distance of origin. Hence their use in deducing epicentres in Bihar would be doubtful. The only two major aftershocks which are fully recorded are those of 16th and 19th January; Dr. Roy has been able to calculate their epicentres satisfactorily. The equally severe shock of 29th August, 1934, at about 9-20 a.m., though sharply felt at numerous Bihar stations, Darjeeling and at Alipore, is not registered by the Agra or the Colaba seismographs.

A comparison of the columns of 'epicentral distances' in Tables 10 and 11 seems to suggest a migration of the centre of aftershock activity further away from Alipore. Up to February 8th the distances of shocks from Alipore ranged from 200 to 250 miles;

in the next four months the distance increased to 300 to 400 miles. Thus between January 15th and June 2nd the maximum increase of the distance from Alipore is 200 miles. The calculated epicentres of subsequent shocks vary haphazardly during the next four months. Within the same interval of time the Agra records show variations of the epicentral distances, from 555 miles to 490 miles, suggesting no migration of the epicentres.

The most important fact emerging from a review of the subject is that the total number of aftershocks, and their frequency during the first few days following the Bihar earthquake, is in marked contrast with the Assam (1897) and Kangra (1905) disturbances, which were followed by an extraordinary number of subsidiary shocks. Oldham mentions the case of the Bordwar Tea Estate in the former area where, for a week after the great shock, the surface of a glass of water standing on a table remained in a constant state of tremor, and at Tura a hanging lamp was constantly swinging for three or four days. At Shillong, a record made on a night seven days after the earthquake showed thirty-three distinct sensible shocks in four and a half hours. In Kangra their frequency was considerably less but in some typical localities within the the epicentre Middlemiss states that an average of thirty shocks in sixteen hours, or one every thirty minutes, occurred on the first day of the earthquake. In spite of the absence of any deliberately kept records following the Bihar earthquake, the general experience of the people is that the main shock was not followed by a train of aftershocks comparable in frequency with the above two cases and that perceptible tremors were not frequent during the first day, or week, or month. This was also the experience of those Geological Survey officers who toured the epicentral area for a period of three months from the first week after the disaster. In view of the size of the epicentre this small number of aftershocks is remarkable, and may possess significance in discussions of the differences in tectonics and geological constitution between the Gangetic Plains, the Assam Plateau and the Sub-Himalayas.

It is generally supposed that these subsidiary tremors are caused by the continuation of those same forces which brought about the first shock and also by the faulted rock masses becoming adjusted to positions of greater stability. In the Bihar area, with its deep mantle of soft inelastic alluvium, the more feeble tremors were presumably damped or smothered before they reached the

surface. In Assam and Kangra, on the other hand, the faulted rock-masses were exposed more or less at the surface, without any appreciable thick cover of sub-Recent unconsolidated deposits and the vibrations were transmitted to the surface without any damping. The above statements may sound contradictory to the usual experience that, in severe earthquakes, the most violently shaken and damaged areas are those situated on alluvial ground or on loosely consolidated rocks. The contradiction is, however, not real. If the initial shock exceeds a certain intensity, the period of the earth-wave motion and the natural period of ground vibration may coincide and the amplitude of oscillation of the ground may thus be greatly intensified; if the surface rocks are loosely aggregated this coincidence may produce a disastrous rocking of the ground. In an aftershock the amplitude and period of earth-waves are usually inconsiderable and are much more feeble than the range and natural period of ground vibration, there is therefore no chance of the former reinforcing the latter; on the contrary the two may tend to oppose with the result that the impulse is smothered. Dr. Dunn does not agree with this explanation, particularly with the last statement, but favours the alternative below.

A second explanation of the relatively small number of aftershocks in the Bihar region is, perhaps, that relief to strain was almost complete as a result of the principal quake. Stability having been obtained in this one great initial movement, further adjustments, with their attendant shocks, were almost *nil*.

The records of great historic earthquakes show that aftershocks are especially numerous following those earthquakes which have originated by movement along faults. They were especially numerous in the earthquakes of Mino-Owari (1891), Kagashima (1893), Messina (1908), Kangra (1905) and Assam (1897), where the crustal movements also produced visible surface faults with both vertical and horizontal displacements. On the other hand a few other earthquakes, also located along fault-lines, such as that of California (1906) were attended by only a few aftershocks. In Bihar, apart from the faulting in the alluvium due to slumping, any faulting in the underlying bed-rock is obscured by the alluvium.

Such occasional strong shocks as have been perceptible in Bihar without any instrumental aid and which have been reported in the

newspapers, possess a tectonic significance. These tremors, originating from many irregularly and widely dispersed centres, from Bettiah in the west to Salana, Assam, in the east, and persisting for a period of at least twenty months after the main shock, might suggest that the Bihar earthquake originated along several branching faults beneath the Gangetic valley. Montessus de Ballore believes that the epicentres of the numerous aftershocks of the Assam earthquake give an accurate representation of the normal seismic instability of that province and define the boundary of the seismic disturbance of 1897. He believes that the various faults which came into existence as the effects of the earthquake have a direct connection with the causes of the aftershocks. He thinks, however, that the epicentres of these various aftershocks are related not to the main crustal movement along a thrustplane, which was the cause of the initial earthquake (a movement of compression from north to south), but to the secondary faults which were induced by that movement, or to already existing faults.[1]

With regard to the distribution of the aftershocks, we are unable to trace any relationship between frequency of aftershocks and any one of the three tracts of maximum intensity of earthquake damage in Bihar and Nepal. The brief reports from the Nepal valley merely remark that 28 shocks occurred in the first six days and 65 shocks during the subsequent nine months. Reports from the Sitamarhi-Madhubani area and the Patna-Monghyr belt are equally vague. From these and other reports there is no suggestion of migration of the aftershock epicentres in the direction of the principal belts of the main earthquake. The aftershocks recorded over a period of three years following the Assam earthquake of 1897 also show a decidedly haphazard arrangement, and no definite line of progression of the centre of instability is discernible.

Has the seismic activity following the earthquake of January 1934 now disappeared from the Bihar area (November 1936) or does it still persist? The graph, fig. 10, kindly supplied by

[1] In his original memoir on the Assam earthquake, Oldham ascribed the phenomenon to crustal movement along a nearly horizontal thrust-plane, accompanied by numerous smaller surface faults. In a subsequent study of the same earthquake, published 27 years later, Oldham suggested an altogether new hypothesis of the origin of the great earthquake. He postulated a deep-seated, abrupt change of a dense magma into a magma of the same composition but of greater volume (bathyseism) as the fundamental cause of earthquakes. He thinks that faults accompanying earthquakes are merely a superficial effect of the deep-seated magmatic origin of earthquakes. With this view the authors of the present memoir are unable to agree.

Dr. S. C. Roy from readings of the Milne-Shaw seismograph at the Alipore Observatory, provides a basis for roughly estimating the total frequency of the aftershocks of a certain degree of intensity. It indicates the decline in monthly frequency of those aftershocks

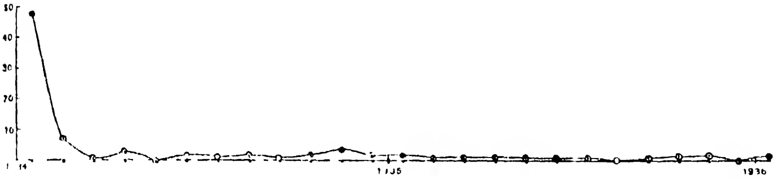

FIG. 10.—Monthly frequency of aftershocks recorded by the Milne-Shaw seismograph, Alipore.

which were strong enough to be recorded by an instrument 300 to 400 miles from Bihar. Probably a number of minor shocks were unregistered at Alipore, although they were strong enough to be distinctly perceptible to the local inhabitants and were reported in the following day's newspapers. However, recognising the limitations of the instrumental record, the decline is very rapid and most marked in the first month. This fact is indicated also by the list given in Table 9, where the recorded aftershocks for the first month are nearly 200 whilst those for the 15th February to 15th March are only 16. This decline is maintained, though not uniformly, through the subsequent months, which show but few marked recrudescences.

The graph tends to support the view that the shock of January 15th relieved the strain more or less completely. An alternative belief is that a large number of the aftershocks have been damped, or completely absorbed, by the thick alluvial mantle of the Gangetic plains.

CHAPTER VII.

THE 1833 AND OTHER SHOCKS IN BIHAR AND NEPAL.

(J. A. Dunn and J. B. Auden.)

Records of the Indian earthquakes of the past show that considerable portions of Northern India have from time to time been subject to earthquake shocks. Mallet's Earthquake Catalogue of the British Association mentions a 'violent earthquake' which took place between 5-30 to 6 P.M. on August 26, 1833, 'all over the centre and east of northern India, especially Nepaul'. The shock was felt in Calcutta, Agra, Lucknow, Tirhoot, Purnea, Patna, Buxar, Allahabad, Monghyr, Katmandu, etc., and also at Lassa (Lhasa). It appears that the shock was fairly violent and lasted from a few seconds up to a minute and that it extended over approximately the same area as the 1934 earthquake. No noteworthy record of any damage in Bihar is given therein but at Tirhoot (probably Muzaffarpur) water was thrown out of tanks 4 feet deep, at Chapra, a chasm of considerable size was said to have been formed in the earth and at Monghyr, Rangpur, Muzaffarpur, Mallai, and other places many houses were destroyed or damaged, and the alarm was great.

An accurate account of the earthquake as it affected Katmandu was given by the Assistant Surgeon, A. Campbell (1833, pp. 438, 564, 636). It is clear that the earthquake of 1833 was not so intense as the recent one. Only 414 people were killed in the Nepal valley, compared with the 3,400 who perished in 1934. The Valley was not so populated a century ago, but, allowing for this, the percentage mortality was certainly less.

The important point is that the forms of the isoseismal lines of the two earthquakes in Nepal must have been approximately coincident, even though those of the 1833 earthquake may not have been so high on the Mercalli scale. Bhatgaon suffered the worst damage in 1833, with a loss of 2,000 houses (42 per cent.). Khokna, a small village, was likewise severely damaged, with collapse of 130 houses; Patan and Katmandu were equally affected, in both earthquakes less so than Bhatgaon. Swayambunath, Kirtipur and Gokarna escaped with slight damage.

Aftershocks were recorded during the 15 days that followed. On October 4th of the same year another violent shock, lasting for half minute, was felt at Katmandu, Monghyr and Allahabad. Another shock occurred on October 18th at Katmandu, Goruckpur (Gorakpur) and Allahabad and several were felt at Katmandu on October 26th, November 8th, 16th and 26th, the last one being severe.

The direction of the main shock of 1833 is variously stated. At Tirhoot the motion was said to have been from east to west; at Buxar from north to south; at Patna apparently east to west; at Calcutta north-east to south-west; at Katmandu apparently east to west. At most of the places, the earth was in almost continuous agitation for 24 hours.

With regard to Monghyr, Lieut. Baird Smith may be quoted (1843, p. 1039*) :—

> 'It is a remarkable fact, that Monghyr seems to suffer more from earthquake shocks, from whatever direction these may come, than any other place in its vicinity. This was observed during the shock from the lateral Himalayan tract, of the 26th August 1833, again during that of the 11th November 1842, and I would say from the information before me, that on the present occasion, the shocks were smarter at Monghyr than at any other spot.'

The latter shock was sufficiently strong to overthrow a portion of the fort wall at Monghyr.

Of recent years such earthquakes as that of 1897 in Assam and the occasional minor shocks up to the Dhubri earthquake of 1930, have all been felt in many of the towns in eastern Bihar. Certain towns have felt these shocks more severely than others which may be even closer to the epicentre. For example Monghyr and Jamalpur have always been more affected than such neighbouring towns as Bhagalpur or towns to the north and south, and the shocks has been more noticeable in Purnea than in the adjacent towns of Katihar or Kishanganj.

There is no doubt that the area in Bihar and Nepal enclosed by isoseismal VIII has been one of seismic activity, although of less frequency than Assam.

CHAPTER VIII.

GEOLOGY AND STRUCTURE OF NORTHERN INDIA.[1]

(D. N. WADIA AND J. B. AUDEN.)

The Tertiary history of the Himalayan region.

A striking feature of India, and one which has probably been appreciated from earliest times, is the division of the country into three units :—

Himalaya
Indo-Gangetic alluvium
Peninsula

The epicentral area of the Bihar-Nepal earthquake lies on the Gangetic alluvium, but as all three units were affected by the earthquake it is proposed in this chapter to give an account of the manner in which this present day configuration has arisen.

During the Palæozoic and Mesozoic periods India was part of the Gondwana continental system which included South America, South Africa and Australia. Three explanations of the structure and break up of Gondwanaland have been advanced: that it was a vast continent covering much of the Southern Hemisphere and later broken up by the submergence of large sections below sea level; that the individual present day continents were connected by isthmuses which have since become submerged; and that the four main countries were originally in juxtaposition but have since drifted apart. We are not, in this chapter, concerned with the areal extent of this old continent; it suffices to remark that the Indian portion of Gondwanaland extended northwards beyond the Indo-Gangetic alluvium and included what is now the Himalaya. The glacial tillite of Upper Carboniferous age which occurs at the base of most of the Indian coalfields and in the Salt Range is probably represented by a boulder bed at Lachi (28° 01′ : 88° 45′) in north-east Sikkim (Auden, 1935, pp. 151, 154), by the Blaini boulder bed of the Simla-Mussoorie-Garhwal hills (Oldham, 1887, p. 144; Pilgrim and West, 1928, p. 5; Auden, 1934, p. 419) and the Tanakki boulder bed of Hazara (Wadia, 1929, p. 153).

[1] The contents of chapters 8 and 9 were written in August 1936, independently of the Presidential Address of Mr. W. D. West (Section of Geology and Geography) entitled "Earthquakes in India" at the 24th Indian Science Congress, 1937.

Coal-bearing Gondwanas are found in the Darjeeling-Assam Himalaya and at the confluence of the Arun and Tamur rivers in Nepal. Gondwana rocks are also well developed in Western Kashmir (Wadia, 1934, p. 150).

To the north of the Gondwana land-mass lay the Tethys geosyncline in which an almost uninterrupted succession of fossiliferous rocks was deposited from the early Palæozoic up to the late Mesozoic period. A subsidiary geosyncline probably occurred between the main Tethys geosyncline and the Gondwana continent, and is represented by the Krol zone of Auden.

Beyond the Tethys ocean occurred another continental mass, Angaraland. Gondwanaland and Angaraland gradually approached each other and this, together with downwarping of the crust in the intervening ocean, permitted the accumulation of a great thickness of sediments in the Tethys. Towards the end of the Mesozoic downwarping ceased; with continued sedimentation the sea had shrunk, by the beginning of the Tertiary era, to such an extent that there was left only a small gulf which was closed to the south-east near Naini Tal and included the area lying between Naini Tal, Dehra Dun, the Zanskar range and Ladakh. It was believed by Pascoe (1919, p. 136) that the Zanskar and Ladakh Nummulitics were deposited in a separate gulf from those of the Naini Tal—Simla, Dehra Dun and Naini Tal area, but recent work by Pilgrim, Wadia, West and Auden has shown the wide spread occurrence of Nummulitics in the area from which they were formerly thought to be absent (Wadia, 1928, p. 196). The assumption of a single gulf seems preferable, as had indeed been suggested by Pilgrim (1919, p. 94).[1] Elevation of the former Tethys zone continued, driving the Eocene sea towards the Arabian ocean. It was not at first, however, pronounced enough to result in any marked erosion of the young Himalayan region, and it is probable, as Pilgrim has suggested (1919, p. 94), that the Murree rocks (lower Miocene) were laid down by rivers draining from the Peninsula rather than from the embryo Himalaya. It was probably just after the deposition of the Murrees (*i.e.*, about Helvetian) that the major Himalayan earth movements took place involving extensive thrusting, since nowhere in the windows exposed in these thrusts is there any trace of rocks younger than the Murrees.

[1] L. M. Davies considers that the Upper Ranikot sea extended from Baghdad to the vicinity of Lhasa. *Nature* 141, p. 202, (1938).

In the latter part of the Mesozoic the Rajmahal lava flows were extruded near the northern edge of the Gondwana continent, whilst at the end of the Cretaceous and during the Eocene vast sheets of lava covered 200,000 square miles of peninsular India, and appeared also over a wide belt in the Himalayan region of North Kashmir (Wadia, 1934, p. 419) and Ladakh (Lydekker, 1883).

By the beginning of the Siwalik period (upper Miocene), the Eocene gulf was completely driven out and the elevation of the Himalaya as a range commenced. Increasing stream activity upon the steepening gradients resulted in strong erosion of the young Himalaya, and the concomitant accumulation of thick deposits along its southern flank. A region that formerly belonged to the Gondwana continent now became downwarped into a young geosyncline well to the south of the Tethys and Krol geosynclines which had given birth to the Himalayan range.

The Siwalik deposits were almost exclusively derived from the actively eroding Himalaya. The most striking feature in these deposits is the great thickness of boulder-conglomerates at the top of the series, which reaches a total of 5,000 feet in the north-west Punjab. To the south-east all the Siwalik stages thin out and boulder conglomerates become less conspicuous, the pebbles being smaller and more scattered throughout the sand-rock.

Considerable speculation has arisen as to the mode of deposition of these boulder-conglomerates. Medlicott was struck by their peculiar abundance at places where the modern Himalayan rivers cross the Siwalik outcrop and he considered therefore that the beds were formed by Pleistocene rivers debouching from the Himalaya along approximately the same courses as the modern rivers (Medlicott, 1864, p. 119).

In 1919 Pascoe (1919, p. 136) and Pilgrim (1919, p. 80) almost simultaneously brought forward the hypothesis that the Siwaliks were laid down by a great river, rising in the Abor-Mishmi area of Assam and flowing north-westwards into the Punjab. The river was called the *Siwalik* river by Pilgrim and the *Indobrahm* by Pascoe. Pascoe also assumed that another river flowed westwards along the north side of the Himalayan chain, along the present Sutlej-Tsangpo alignment.

Neither Pascoe nor Pilgrim much favoured the idea put forward by Medlicott that the boulder-conglomerates were laid down by a system of southward flowing consequent streams from the

rising Himalayan chain. Both were impressed by the continuity of the Siwaliks from the Punjab into Assam and by the fact that the boulder-conglomerates are not confined to the vicinity of the debouchures, but are often well developed in the Siwalik outcrop between the rivers. Pilgrim (p. 88) was, however, willing to allow that northern tributaries were instrumental in supplying some of the boulders. He believed that the special abundance of conglomerates in the Punjab was due to the blocking of the Siwalik river by elevation in the Kashmir-Jammu area.

It is probable that no one explanation will account for these conglomerates and that a combination of factors led to the deposition of the upper Siwaliks :—

(1) elevation of the Himalaya ;
(2) increased precipitation and active erosion by consequent streams ;
(3) redistribution of boulders from these consequents by a river flowing along the downwarped southern border of the mountain chain.

The Siwalik boulder conglomerates give place insensibly to the older Gangetic alluvium (*Bhangar*). Where the Siwalik rocks are lying horizontally or with low dips it is often very difficult to distinguish them from the more recent gravels. Along certain zones, however, folding has caused the tilting of the Siwaliks into vertical and even inverted positions. In such cases the later gravels may be seen to rest with a profound but quite local unconformity upon the up-ended Siwaliks.[1]

Summarising the geological structure of northern India we have the following main units from north to south :—

(1) the zone of mainly pre-Tertiary rocks of the lower and greater Himalaya in which thrusting is on a colossal scale ;
(2) the zone of visible mid-Tertiary and Siwalik rocks, with considerable folding and faulting ;
(3) the alluvial zone of the Gangetic trough which conceals both Siwaliks and peninsular rocks ;
(4) the Peninsula.

[1] Recent work by De Terra would suggest that the fans of Siwalik boulder conglomerates in northern India merge into ground moraines derived from one of the ice advances during the Pleistocene ice age [De Terra : *Proc. Am. Phil. Soc.*, LXXVI, p. 791, (1936) ; *Nature*, Vol. 137, p. 686, (1936)], a fact which lends support to La Touche's idea of increased precipitation during this period [La Touche : *Geol., Mag.*, VII, p. 193, (1910)].

The structure of the Himalayan region.

After this brief historical survey, it is necessary to discuss the inter-relationships of the various units just enumerated. The discussion may be conveniently divided into the following sections:—

(1) Thrusts within the Himalaya and bounding the pre-Tertiary and Nummulitic rocks from the post-Nummulitic.
(2) Thrusts and folding within the Siwalik zone.
(3) The Siwalik-alluvium boundary.
(4) The Indo-Gangetic trough and the evidence of folding and faulting at its floor.
(5) Evidence of recent instability.
(6) The sub-alluvial boundary between the Siwaliks and the basement of peninsular rocks.

(1) Thrusts within the Himalaya and bounding the pre-Tertiary and Nummulitics from the post-Nummulitics.

The thrusts under this heading may be divided into those which cause displacements between rocks entirely of pre-Tertiary age, and those which involve the Tertiaries.

Medlicott long ago (1864, pp. 92, 94, 102; Oldham, 1893, p. 349) recognised the faulted relationship between the pre-Tertiaries and the Tertiaries. The term 'main boundary fault' was used by Medlicott to define the boundary plane between the Sirmur series (Nummulitic and Murree) and the Nahan or lower Siwaliks. The tectonic significance of these faults is still a subject of discussion (Auden, 1934, p. 446). Medlicott's idea of cliff faces only slightly modified by subsequent faulting is certainly untenable. It is quite certain that some of the faults are inclined at gentle angles towards the north and imply translation of rock masses for very great distances. It also seems that the faults do not in every case mark the boundary of deposition of the Siwalik rocks to the north-east.

The Krol thrust has been traced from near Subathu to Dehra Dun. From Dehra onwards to the south-east it is obscured by alluvium, except for windows of the thrust within the mountains. The thrust undoubtedly joins up with the main boundary fault of Middlemiss east of the Ganges which has been traced to the Nepal frontier. That movement along this thrust has been of great dimensions is shown by the occurrence of windows of Nummulitic

rocks below the thrust both at Solon, on the Kalka-Simla railway, and near Narendranagar, the new capital of Tehri Garhwal State. Considering solely the evidence of these windows the minimum movement in a horizontal sense is about 5 miles. Auden believes, however, that the thrust plane crops out on the north limb of the Mussoorie syncline from Sayasu, on the Tons river, down to the western slopes of the Bhagirathi valley near Tehri. The minimum displacement in this case would be 20 miles (Auden, 1934, Plate 24, fig. 2 : 1937, Plate 36).

The same thrust as the Krol thrust and the main boundary fault of Middlemiss has been seen in Nepal near south-west of Katmandu and just north of Udaipur Garhi (Auden, 1935, pp. 144, 146). This thrust clearly continues eastwards into the Darjeeling area and is the plane dividing the Gondwana rocks of Darjeeling from the underlying Siwaliks.

Only brief mention need be made of the thrusts situated within the Himalaya and involving pre-Tertiary rocks.

Wadia has traced two concurrent, more or less parallel, thrusts (Panjal thrusts) along the foot of the Pir Panjal range from eastern Hazara, round the syntaxial bend of the North-west Himalaya to as far south-east as Dalhousie. The first of these has thrust the Murrees underneath the Eocene and older fossiliferous rocks, while the inner thrust has pushed the Archean and pre-Cambrian sediments over the latter (Wadia, 1931, p. 189).

In the Simla Hills, Pilgrim and West (1928) and West alone in recent years (1935, p. 74 ; 1936, p. 72 ; 1937, p. 79) have shown the existence of several thrusts which involve translation of tectonic units over great distances.

Between the Jumna river and Gungti hill (29° 46′ : 78° 55′) Auden (1937, p. 421) has shown the existence of the Garhwal nappe, based upon the Garhwal thrust, which he considers possibly to root in the main Himalayan range. The displacement along this thrust-plane may be 50 miles.

The possible equivalent of the Garhwal thrust in Nepal and Darjeeling is the thrust which has caused the superposition of the Dalings and Darjeeling gneiss upon the Gondwana rocks of that area (Auden, 1935, p. 144). The Dalings strongly resemble the rocks of the Garhwal nappe.

The chief difficulty with which we are confronted is the question of the age of these thrusts. Near Shali (31° 12′ : 77° 17′),

Solon (30° 55′ : 77° 07′) and Narendranagar (30° 10′ : 78° 17′) Nummulitics and Dagshai rocks occur as windows below the thrusts. The movements are therefore post-Dagshai (post-Burdigalian). Since no Siwalik rocks are found in the windows, it might be assumed that the thrust movements took place after the Burdigalian but before the Siwaliks had time to be deposited there. This would make the movement about Helvetian in age. If, however, as is probable, the Siwaliks never extended so far to the north-east, this argument fails, since it is possible to imagine the thrusting as having occurred a considerable time after the Nummulitics and Dagshais had been laid down while Siwaliks were being deposited elsewhere. The main boundary fault may be regarded as a boundary north-east of which the Siwaliks were, in general, never laid down, though in Poonch outliers of Siwaliks have been mapped north of this boundary.

That some of the movement along the Krol thrust is definitely more recent than Helvetian is proved by the frequent juxtaposition of pre-Tertiaries upon Nahans between the Jumna and the Nepalese frontier. Further, in places even the upper Siwalik conglomerates are involved in overthrust by the pre-Tertiaries. Ten miles north-west of Dehra the boulders of these conglomerates are so shattered that it is impossible to obtain a hand specimen of them. Similar overthrusting occurs at Bilaspur on the Sutlej (31° 20′ : 76° 45′) (Auden, 1934, p. 444). These movements must be of lower Pleistocene or even later age. It is difficult to believe that the major horizontal movements of the Krol and Garhwal nappes over a distance of several miles took place as late as this. By lower Pleistocene times the rising Himalayan chain must have been dissected to such an extent into blocks by deep erosion that the upper nappes would have already been worn away into outliers. The formation of these upper nappes can only have taken place before erosion had proceeded to such an extent that the outcrops of the nappes in the direction of movement had been divided off into separate patches, unable to translate the stresses as a unit (Auden, 1937, p. 429). Both the Krol and Garhwal nappes have been strongly folded in the Simla-Mussoorie region, probably as a result of resistance offered by the floor upon which the movement was effected. There has since been erosion of these thrusts to give rise to the windows and zig-zag outcrops which now occur, and it may be accepted that the major part of the movements took

place before river dissection had reached its present pronounced stage. On the other hand, the post-Siwalik movements along these thrusts must have occurred after considerable erosion. We are led therefore to assume that there has been more than one period of movement, the earlier and stronger movements perhaps during the Helvetian, and the later movements during the Siwalik and post-Siwalik.

(2) Movements within the Siwaliks.

The same conclusions drawn from an examination of the Krol and Panjal thrusts apply to the movements which took place within the Siwaliks. Excellent sections of Siwalik overthrusts are provided by Middlemiss for the area between the Ganges and the Nepalese frontier. Not only are the various stages of the Siwaliks faulted against each other, but the upper Siwaliks are found in places to rest unconformably upon lower Siwaliks, as a result of late Pliocene or early Pleistocene movements. Further, the whole Siwalik formation has been folded by still later Pleistocene movements. The Siwalik deposits of the Rawalpindi and Attock districts, aggregating over 16,000 feet in thickness, have been folded into the Soan geosyncline, occupying the Potwar basin. The northern flank of the Soan syncline, consisting of the entire Siwalik sequence, including the lower 3,000 feet of upper Siwaliks, is ridged up for many miles into a vertical position, the truncated tops of the wall-like strata being unconformably overlapped by the higher beds of the upper Siwaliks, superposed in turn by gently tilted strata of the older alluvium of the Punjab.

(3) Siwalik-Older Alluvium boundary.

Further evidence of very recent movements has been obtained by studying the relationship between the Siwaliks and the alluvium. Clear evidence of post-Pleistocene orogenic movement has been obtained by Pascoe, Wadia and H. M. Lahiri in the course of survey work in sub-Himalayan region of the Punjab :—

(i) Sir Edwin Pascoe (1920, pp. 395, 397, 451) observed tilted and almost vertical Pleistocene (post-Siwalik) conglomerates between Saidpur and Rawalpindi and in one case near Golra he saw these conglomerates folded into a syncline perched upon steeply dipping Murrees and Nummulitics.

(ii) Wadia recorded vertically bedded Pleistocene conglomerates some thousands of feet in thickness running for many miles along

the strike of the north rim of the Soan syncline near Gorakhpur (Rawalpindi district). This conglomerate contains fossil mammals which according to some authors are of mid-Pleistocene age. The tilted conglomerate unconformably underlies horizontally bedded older alluvium at some places while at other places, only a short distance away, the relations are apparently quite conformable (Wadia, 1928, Plate 9).

(iii) Lahiri has lately observed Siwalik strata overthrust on horizontally disposed and undisturbed clays and pebble-beds of the *dun* area (Pleistocene) between Kalka and Nalagarh. He has also seen upper Siwalik strata faulted against sub-recent or Pleistocene alluvium in the Suttej valley, Hoshiarpur district, of the Punjab (Lahiri, 1935, p. 73 and 1936, p. 78)—figs. 11 and 12.

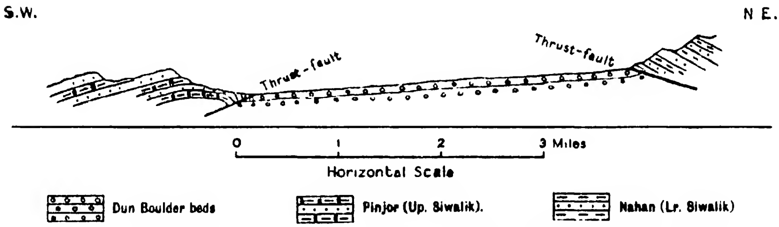

FIG. 11.—Section across Dun, between Nalagarh and Kalka (by H. M. Lahiri).

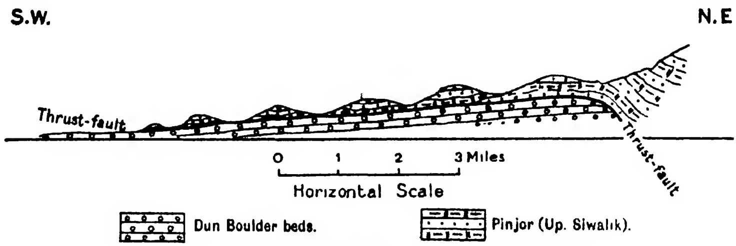

FIG. 12.—Section near Mastanpura (by H. M. Lahiri).

(iv) In the Dehra Dun area Oldham and Auden have found a pronounced unconformity between the upper Siwalik conglomerates and the overlying Dun gravels. The Siwaliks have been thrown into an unsymmetrical syncline, the northern limb of which is locally overturned so that the upper Siwalik conglomerates are inverted. Upon these conglomerates rest almost horizontal Dun gravels (Oldham, 1893, plate opposite p. 482, and Auden, 1937, plate 37).

Only eight miles to the south-west of this zone of unconformity, there is probably complete conformity between the Dun gravels and the Siwaliks. Exactly similar relations have been observed in the centre of the Soan geosyncline (p. 125) the pronouncedly unconformable contact (overlap) of the older alluvium at the rim of the syncline is replaced by apparent conformity between the upper Siwalik and the older alluvium at the centre of the basin. The local folding in both these areas was clearly Pleistocene if not post-Pleistocene in age. Following the folding there has been uplift and strong incision of the gravels by streams flowing from the Mussoorie range. Ravines in the gravels from 400 to 600 feet in depth are common.

The boundary between the Siwaliks and the Gangetic alluvium on the southern side of the Siwalik range varies from place to place. The work of Middlemiss (1890, p. 122) east of the Ganges may be quoted :—

'There are not wanting signs that the southern margin of the hills has become, or is tending to become, a reversed fault...... Taking a definite portion of the country south of the Patli dun (see section V), what has become of the southern half of the normal (unsymmetrical) anticlinal in the sand-rock and Siwalik conglomerate, which we may assume by analogy was once present ? There is no reason to suppose it denuded away entirely any more than the northern half; but there is strong reason for believing that, if we accentuate the earth movements which in the gently undulating area of the Kotah dun were nevertheless able to produce so sharp a bending to the south with slight inversion, we shall arrive, in the more crushed area of the Patli dun, to a state of complete inversion and production of a fold-fault......

'I see no escape therefore from the general conclusion that, wherever the southern margin of the Siwaliks shews no relic of a "*dejettement*" to the south, it is because a fold-fault has supervened along what is now a limit of deposition for the Bhabar zone of gravels, sands and clays.'

W. N. W. of Hardwar the Siwalik range is anticlinal in structure with the upper Siwaliks of the south-west limb dipping south-west below the alluvium. This alluvium appears to cut unconformably across the upper Siwalik stage on to the middle Siwalik stage. Southward dips of the Nahans below the alluvium are seen in Nepal in the Rae *nala*, point 2038 (26° 50′ : 86° 26′). The alluvium in this area has overlapped folded and eroded Siwaliks, and there seems to be no indication of any fold-fault such as Middlemiss assumed to exist further to the west. The significant point is, however, that folding and erosion persisted between the deposition of the Siwaliks and that of the alluvium.

(4) The Gangetic Basin and the folding in its floor.

The most important geological event, subsequent to the upper Siwalik and the glacial epoch, was the filling up, by sub-aerial and fluviatile deposits, of the Indo-Gangetic trough, the great down-warp lying between the northern edge of the Peninsula and the recently built Himalayan chain. This basin is 250 miles wide in its broadest part and 1,500 miles long from Sind to the outskirts of the Arakan Yoma. Surface features and gravity observations indicate that it is deepest in the central Gangetic portion and shallows west of Delhi and east of the Rajmahal hills.

According to general belief this sunken belt, which in pre-Eocene times formed part of the peninsular table-land south of the Tethys, was developed concomitantly with the elevation of the Himalaya and is of the nature of a fore-deep. Continual loading of this belt by sedimentation since the first uplift of the mountains may have accentuated the sinking, but the two processes, sedimentation and depression, have kept pace and so arose the great plains of India.

We know from the existence, for example, of characteristic Gondwana rocks on the northern rim of this alluvial belt, that its substratum is an extension of the peninsular rocks, *viz.*, Archean gneiss, with areas of Vindhyan and Gondwana sediments.

Structurally this wide down-warp has been in process of formation since the withdrawal of the Himalayan sea of post-Nummulitic times. Post-Eocene deposits in the northern half of the trough are, for the most part, buried under later Pleistocene alluvium, and belong to the Murree series of western Punjab. They are represented further east by the combined Dagshai and Kasauli series, which are overlain by the enormous system of Siwalik deposits, which in turn are succeeded by the Indo-Gangetic alluvium. The Murrees are about 8,000 feet thick, while the Siwaliks aggregate over 15,000 feet near the northern rim of the Gangetic trough, so there is reason to assume a like thickness for the submerged portion of these two series of deposits in the region to the south. We have no data for estimating how far southwards these series extend, but it is possible that the Murrees stretch much further south than the Siwaliks (Wadia, 1932, p. 88). The hypotheses regarding the probable thickness and southern limits of the Murree-Siwalik deposits lying under the Gangetic alluvium are referred to later (pp. 132, 133).

There is reason to believe that the floor of this wide depressed belt of the Peninsula, loaded with this great thickness of Tertiary and post-Tertiary sediments, must be under strain, a strain accentuated by the subsidiary folding at the bottom of the synclinorium. There is also reason to believe that the series of parallel fractures of the 'boundary faults' type, so conspicuous in the exposed part of the Tertiaries, also prevail in the part covered by alluvium. The sagged floor itself, to judge from what is actually seen at its northern margin, is probably disrupted by fractures and fault-planes, while the wrinkling of strata, seen in such intensity in areas like the Margala and Kala Chitta hills of north-west Punjab, where the Himalaya merges into the plains, is also continued, though with decreasing degree, to a considerable distance southwards. The behaviour of the alluvial zone of the Ganges valley in Bihar during the earthquake suggests the possible occurrence of a number of faults beneath the alluvium. This subject is referred to again in a later section.

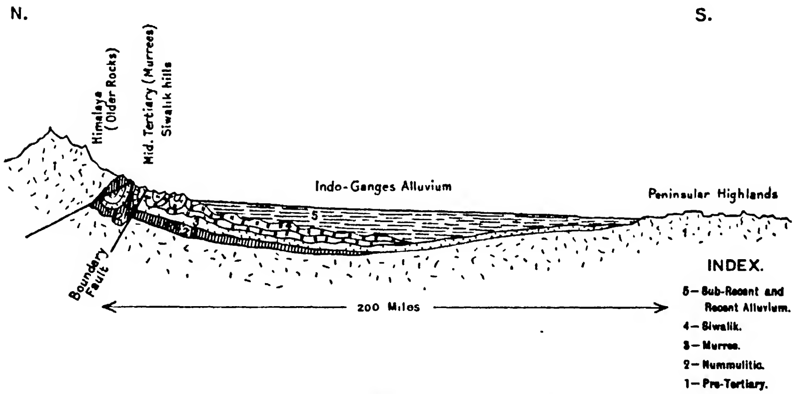

FIG. 13.—Diagrammatic section of possible sequence within the Indo-Gangetic trough.

(5) SIGNS OF RECENT INSTABILITY.

In the preceding pages examples have been cited of Recent or sub-Recent earth movements along the southern flanks of the Himalaya. There is also evidence of recent instability in the middle Himalayan region. Much of this evidence is from north-west India, beyond the area with which this memoir is primarily

concerned; however, it is presumed that interpolation of these structural features to the less known areas further east is permissible.

In Kashmir the Pleistocene *Karewa* formation has been elevated and tilted along the flanks of the Pir Panjal range; the extent of this elevation is as much as 5,000 to 8,000 feet according to recent estimates. These Karewa beds occur on the north-east flank of the Pir Panjal at heights up to 11,500 feet, and it is possible that they are related to the sub-ærial and glacial deposits across the summit of the range, on the opposite south-west flank. Fossils of post-Tertiary animals and plants both of terrestrial as well as fluviatile and lacustrine habitat are found at many localities at heights at which they could not have lived; their occurrence, therefore, in their present position as well as the fact of the folding and inclination of the Karewa beds, which in places possess dips as high as 40° (in a north-east direction), are clear proof of sub-Recent elevation of the Kashmir mountains.

De Terra in contrasting this youthful crustal deformation with the Mio-Pliocene upheaval of the Himalaya says:—'this gentle crustal warping is nothing but a different manifestation of the same forces of folding which previously led to much more intricate rock structures. The Tethys formations were rendered inflexible by tight compression, but they yielded once more to younger deformation which may be characterised as a broad crustal bulging accompanied by a differential gentle warping of its upper structure' (De Terra, 1935, p. 68).

Many examples may be seen in the Himalaya of dissected gravel terraces lying high up along the sides of the modern valleys. Some are given below:—

River.	Locality.	Co-ordinates.	Height of terrace above river bottom.
Sutlej	Bilaspur	31° 20′; 76° 45′	400 feet.
Giri	Hill 3619	30° 36′; 77° 28′	1,600 „
Aglar	Lagrasu	30° 30′; 78° 07′	1,200 „
Jakhan	Bimet	30° 14′; 78° 15′	800 „
Bhagirathi	Dang	30° 28′; 78° 24	1,100 „
Bhagirathi	Tehri	30° 23′; 78° 29′	700 „

A system of 4 to 5 dissected gravel terraces is commonly observed in the three main valleys (Jhelum, Kishenganga and Chenab)

of the Kashmir mountains. The highest terrace is over 1,200-1,500 feet above the present valley-bed. These terraces are in part built of moraines of the later phases of the Pleistocene glacial epoch of Kashmir, and De Terra is of the opinion that the Jhelum terraces are connected with the three last ice advances and their respective interglacial periods. It should be pointed out that these gravels are obvious river gravels, with well rounded boulders some of which are foreign to the immediate neighbourhood in which they are now found. The history of the elevations and depressions responsible for the various terraces found in the Himalayan foothills is complicated and has not yet been worked out. It may be assumed that the height of these gravels above the modern valley bottom in many cases represents, in part, the elevation which has occurred in recent times.

Post glacial uplift of the main Himalayan range is indicated by the deep incision which has taken place in the Karewa platforms of Kashmir, which contain interbedded glacial moraines at two or three different levels. In a few cases the Karewas show steep dips with monoclinal folding of the strata. Similar uplift is also seen in the glaciated Bhagirathi valley below Gangotri. Here a deep gorge has been formed since the valley was forsaken by the Pleistocene forerunner of the Gangotri glacier. Unfortunately it is still not known to which period of ice advanced the glaciation of different parts of Kashmir and the north-east face of the Pir Panjal is due; the period of glaciation of the lower parts of the Bhagirathi valley by Gangotri temple is also uncertain. Hence it is impossible to date the uplift and incision accurately, but it is certainly middle Pleistocene or later.

Further evidence of recent rejuvenation, probably a consequence of uplift, is afforded by the steepening of the transverse V-profiles in many of the Himalayan rivers—such as the Bhagirathi river of Tehri Garhwal.

In Kashmir and Sikkim, river capture provides further indirect evidence of uplift. Oldham gives a very good instance of river capture in the Sind tributary of the Jhelum river in Kashmir and Garwood has described the capture of the east-west subsequents by actively north-cutting consequents, which he attributes to uplift in the Kangchenjunga region.

(6) The sub-alluvial boundary between the Siwaliks and the basement of Peninsular rocks.

There is unfortunately little information with regard to the extension of the Siwaliks below the alluvium towards the Peninsula. Tertiaries are absent along the northern edge of the Peninsula, and hence the boundary between the continuous outcrop of the Siwaliks subjacent to the Himalaya and the basement must lie concealed below alluvium. Siwaliks crop out along the southern border of Shillong plateau, so that it might be assumed that they lie moderately close to the northern edge of the Peninsula near and west of the Rajmahal hills. Further, the extensive east-west outcrop of the Siwaliks in the Potwar trough north of the Salt Range has the appearance of being the actual width across the regional strike of a band which, over the greater part of its extent, is concealed below alluvium. The Potwar geosynclinal trough (fig. 14) contains 25,000 feet of Tertiary sediments representative of all stages from Eocene to middle Pleistocene. It is regarded as only a small scale replica of the much larger Indo-Gangetic trough to its south-east and tectonically formed on the same plan. By inspection of the geological map, therefore, it might be assumed that the average width of the Siwalik zone (including the present outcrop and the portion concealed below alluvium) is about 90 miles along the foot of the Himalaya.

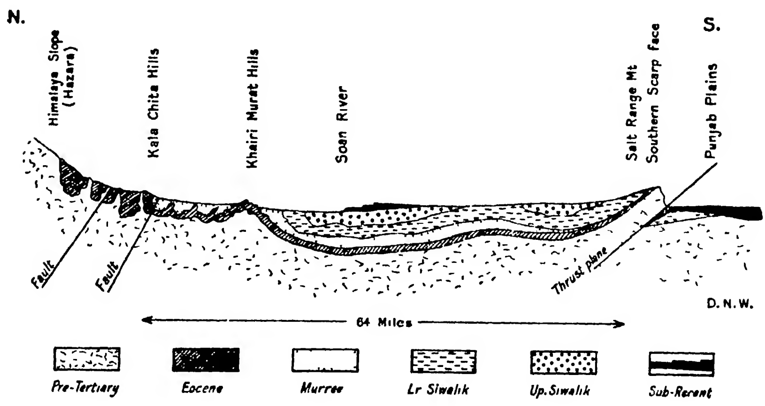

Fig. 14.—Section across the Potwar geosyncline.

The recent geophysical survey, carried out by the Survey of India necessitates, however, some caution in these assumptions. Colonel Glennie states (1935, p. 56):—

'The flat alluvial plains of North Bihar, devoid of marked topographical and geological features, form an ideal field for geophysical exploration. Pendulum results indicate, at the deepest part, a depth of over six thousand feet of light sediments, and since the underlying rocks have probably a notably greater density, the torsion balance should be very suitable for charting the lower surface of the alluvium. Again, it is known that the rocks of the Peninsula bordering the south edge of the Gangetic plain contain minerals capable of causing magnetic effects, so magnetic investigation also is promising if these rocks underlie the alluvium.'

The gravimetric and magnetic results obtained by the Survey of India are satisfactory in being consistent, and it may therefore be assumed that the change in physical properties between a denser and more magnetic foundation and a lighter and less magnetic covering, represented by the line drawn in the section on page 59 of the quoted report, is a real one and is abrupt. If the Siwaliks were present below Motihari as a layer between the alluvium and the basement, it would be expected that the change in physical properties would not have been so abrupt as is actually so, since the Siwaliks, being at a greater depth and more consolidated, would have a higher density than the alluvium, though less than the basement. The consistent results of the Survey of India would seem to indicate either that the Siwaliks are absent beneath Motihari, or that the combined Siwalik and alluvial formations are only 6,500 feet in thickness at this locality, and are both sharply contrasted in physical properties from the basement. The matter can only be one of speculation, but in view of the unquestionable thickness of the Siwaliks in Nepal, only 30 miles to the north of Motihari, we find it hard to believe that they are totally absent below Motihari, and we are led therefore to accept the second alternative. As far as this section is concerned, it is only necessary to add that the extent of the Siwaliks towards the south-west may not be so great as inspection of the geological map would seem to suggest.

Thickness of the alluvium.

There is little or no geological information about the thickness of the alluvium. The deepest borehole (at Ambala) known to

us is only 1,612 feet and did not touch the rock-bottom. Numerous bores have been put down in the United Provinces and North Bihar, but none of them is over 600 feet and in no case has rock-bottom been reached. This is not surprising because, even if the bottom of the alluvium had been reached, there might still be a considerable thickness of Siwalik rocks to penetrate below the northern part of the alluvium before the peninsular basement was reached. Indeed, the gradation downwards from alluvium into Siwaliks would make any estimation of the thickness of the alluvium towards the north very difficult.

The Siwalik deposits reach a thickness of from 16,000 to 18,000 feet, and we may assume that the thickness of the alluvium, laid down under analogous conditions but in a shorter time, is less. R. D. Oldham (1917, p. 5) has stated his opinion as follows:—

'The clearly defined character of the southern margin of the hills towards the plains, running with a regular sweep along the foot of the hills, and the absence of detached outliers rising out of the alluvium, irresistably suggests that the boundary is determined by a structural feature similar to the main boundary and the faults in the Siwalik area, and though no direct measurement of the depth of the undisturbed alluvium is possible, the fact that it is identical with, and a continuation of, the Siwalik deposits affords a tolerably certain indication. The total thickness of the Siwaliks, in the Kumaon and Garhwal districts, was estimated by Mr. Middlemiss at an average of 16,500 feet; Mr. Medlicott estimated the thickness of the Siwaliks north of Hardwar at 15,000 feet, and the whole thickness is not exposed on this section. We may therefore take it that the depth of the alluvial deposits, being a continuation of these Siwaliks, is not likely to be materially less than 15,000 to 16,000 feet at the northern limit of the plains, and we may safely say that the alluvium at the northern edge of the plains is very improbably much greater or less than about three miles in depth.'

We turn next to the geodetic data. The earlier work of the Survey of India was interpreted by Burrard. At one time he considered that the Gangetic alluvium occupied a narrow rift at the foot of the Himalaya, the maximum depth of which was 20 miles or over 100,000 feet (Burrard, 1912, p. 11). This figure has been discarded by the Survey of India, since the geodetic evidence now leads to other results, and a rift of such dimensions is in opposition to geological and geophysical experience. From an examination of the geodetic data, R. D. Oldham, in the same memoir as that from which we have quoted above, considered that the depth of the alluvium reached a maximum, towards its northern edge, of 15,000 to 20,000 feet (1917, p. 82). Cowie, using the same data, adopted even higher figures. On Plate 1 of Cowie's paper,

both the Punjab and United Provinces—Bihar troughs are shown as having thicknesses of 20,000 feet (1921, p. 6).

Recent work has led E. A. Glennie to estimate the thickness as considerably less (1932, p. 18). Using the gravity results from Gonda and Gainsari stations, he estimates that the $g-\gamma_F$ anomalies are -50 and -52 mgals. respectively. Adopting a density for the alluvium of 2·16, and presuming a density of 2·67 for the basement, Glennie calculates that the depth of the alluvium is only 6,500 feet. The same figure is adopted by Glennie in his report on the recent geophysical survey of Bihar, a portion of which has already been quoted in the preceding section (1935, p. 59). A north-south section is given in this report running through Motihari (fig. 16). The $g-\gamma_F$ anomaly at Motihari is -56 mgals. a figure slightly in excess of that of Gonda, but not enough to affect materially the figure adopted from the earlier paper. The question of the possible presence of Siwalik rocks between the alluvium and the basement was not discussed by Glennie, but, as we have already stated on page 133, we find it hard to believe that the thick Siwalik deposits of Nepal should have died out completely below Motihari, only 30 miles to the south. The estimate of 6,500 feet is evidently assumed by Glennie to apply to the combined Siwaliks and alluvium. Accepting the assumptions made by the Survey of India, this figure fits the geodetic data, but it does not conform with geological facts. It cannot be regarded as definite and may well be greater.

Instability of the sub-Himalaya and Gangetic trough.

We come next to the question of the relative stability of the geological units described.

The highest nappes, such as the Pir Panjal and Kashmir nappe, the Jutogh nappe of the Chor area, and the Garhwal nappe east of Dehra Dun, are so dissected by erosion that they occur only as outliers incapable of receiving any lateral stress from outside. They are, therefore, inert and can only play a passive part in modern earth-movements. The same nappes almost certainly are to be found in the main Himalayan range, where dissection is less and the units are able to receive and translate lateral stresses. But the distance of the main ranges from the plains and the lack of observations do not permit of further discussion about these thrusts.

Coming to the Murree, Krol and Main Boundary thrusts the inferences about stability are less sure. The Krol thrust is highly folded and considerably dissected, so that widespread horizontal translation along the original thrust plane would be impossible. On pages 124 and 125 it was considered that there may have been two stages of movement; the first and greatest movement during the Helvetian and the second during the Pliocene and Pleistocene. Auden believes that the later movements may have occurred in response to isostatic uplift consequent on tectonic accumulation during the earlier Tertiary. It is possible that these movements utilised those portions of the faults and thrust planes already in existence which permitted easy yield. Isostatic elevation of a mass must result in partial freedom from the lateral pressure which had previously occurred on all sides when the mass had been at a lower crustal level, with the consequence that there would be a tendency for the elevated portion to expand outwards as well as to rise vertically. Outward movement towards the south-west would be only possible along those portions of the thrust-planes which dipped to the north-east, and it is possible that the over-thrusting of the pre-Tertiaries upon the Siwaliks may be explained as a rejuvenation of movement along the suitably situated portions of the earlier thrusts.

The boundary between the Siwaliks and the alluvium is known, particularly from recent work of Wadia and H. M. Lahiri, to have been unstable within recent times—we may suppose since the upper Pleistocene or even post-Pleistocene. The thrusts mentioned on pages 126 and 127 appear to indicate more than merely the horizontal component of isostatic uplift, since the horizontal displacement of the thrust near Mastanpura would appear to be at least 1½ miles in extent. The horizontal displacement near Rawalpindi appears to be inconsiderable.

As stated on p. 132, we do not consider the buried boundary between the Siwaliks and the peninsular basement to be of tectonic significance. We consider it to be an overlap across the Peninsula similar in nature to that now seen between the alluvium and the Peninsula. There is a possibility, however, that thrusts occur within the concealed Siwaliks of the same type as are known to occur within the present outcrop of the Siwaliks, between the Punjab and Nepal. The postulated existence of a considerable amount of folding in the floor of the Gangetic basin underneath the alluvium must be taken into account.

These thrusts within the Siwaliks are likely to be shallow features, resembling those of the Swiss Jura mountains so graphically figured by Buxtorf. The Jura mountains appear to be based upon a thrust plane which has utilised the mobile *Anhydritgruppe* of the Triassic. The Siwaliks and the peninsular basement are two units of such different degrees of competence that it is quite likely that the boundary between them is tectonic (the former surface of overlap being utilised later as a thrust plane), and that the Siwaliks have moved as a single unit across the basement in response to compression, while at the same time they were folded and thrust within themselves in the same way as the Jurassic and Cretaceous rocks of the Swiss Jura mountains, (Auden, 1937, p. 417).

Post Mesozoic movements in the northern part of the Peninsula.

(J. A. DUNN.)

We may now remark on certain movements which have taken place on the southern side of the Gangetic Plains and within the northern part of the Peninsula itself. Here, the evidence on which we have to rely is sparse and has not that preciseness of meaning which evidence in the Himalaya provides. For our yardstick we have now to rely on the degree of erosion of old peneplains by rivers working almost at base level over most of their distance, and as datum lines we have only the base of the Gondwanas, the base of the Rajmahal and Deccan Traps, and in addition a few coastal Tertiary deposits. However, even with the paucity of information at our command, certain salient features more or less conclusively demonstrate a succession of uplifts during the period from early Tertiary down to the present day.

Immediately south of the epicentral tract is the north-east corner of the Peninsula around which the Gangetic alluvium laps to the north and east. At this corner there is quite a wide expanse of Rajmahal traps associated at the base with late Gondwana sediments containing plant remains. These late Mesozoic rocks directly overlie the Archean gneisses which stretch away to the west in the form of an old plain. The base of the Rajmahal rocks, as now exposed along their western margin, is practically at the level of

the present plain surface of Archean rocks, hence it is apparent that at this point there could never have been uplift since the lavas were poured out, although there may have been subsidence. As the lavas disappear to the east below the alluvium at a lower level than the western margin, it is also apparent that the lavas have been tilted slightly to the east.

Surveying the country west of the Rajmahal traps, and along the edge of the Gangetic alluvium, we find a terrain possessing all the earmarks of an old plain surface of Archean gneisses and schists at a general level of 250 feet, deeply decomposed and with occasional residual hills, usually of quartzite, rising a few hundred feet higher. South from here the surface gradually rises to plateaux which will be mentioned shortly, but the character of the country retains its monotonous simplicity as far west as Sasaram. The edge of the alluvium overlaps this gneissic plain very irregularly, and far out in the alluvium, particularly near Gaya, residual hills project above the general level of the plains.

At the Son river a sudden change becomes noticeable along the border of the alluvium and the Peninsula, for here the alluvium abuts against the Kaimur scarp bounding the Kaimur plateau which rises several hundred feet above the plains. This plateau, with its gently rolling uplands, is characterised by the steep gorges through which the streams debouch from the scarp on all sides, although further north the streams are at base level. This erosion at the edge of the plateau provides a characteristic juvenile topography, in contrast with the surface of the plateau above and of the plains below. On the southern side the Son river has cut a narrow valley (in places, perhaps, along a fault), separating the Kaimur plateau from a similar plateau to the south and at about the same level, and which has clearly been uplifted in late Tertiary times.

Returning now to the country south from Gaya and Dumka. South from Gaya the general level of the country gradually rises, with here and there sudden increases of gradient consequent upon vagaries of denudation, until eventually a height of 2,000 feet is obtained. But on this gradually rising surface, for the most part flat or gently undulating, there are residuals such as the curious mass of Parasanath rising to 4,480 feet and others rising to much lesser heights, and consisting mostly of Archean quartzites and schists. None of these lower residuals carry any clear signs of an older surface, and, although it is probable that some of them are the

remnants of an older level surface, none possess any features which would suggest it.

On its southern side the Hazaribagh plateau is separated from the Ranchi plateau by the east-west Damodar valley, some 20 miles in width, which provides one of the interesting structural features of Chota Nagpur. The north and south sides of this valley are steep straight escarpments enclosing large basins of Gondwana rocks which may be followed east beyond the line of this valley to the Jharia and Raniganj coalfields.

Noting the general level of the basement of these Gondwana basins, from the Hutar coalfield in the west to the Raniganj coalfield in the east, there is a definite increase in the elevation of this basement as we go west. The Raniganj field, being close to the edge of the Rajmahals (where, as we have already pointed out, there cannot have been post-Mesozoic uplift), there cannot have been post-Mesozoic uplift at the eastern edge of this field; there may have been post-Mesozoic subsidence, but it is probable that most of the subsidence of these coalfields, which carried their base to over 2,000 feet below sea level, took place during their deposition in Mesozoic times. However, apart from these considerations, the evidence indicates, therefore, a gradual tilt along the Damodar valley with uplift to the west. Where it is bounded by the Hazaribagh and Ranchi plateaux the scarps indicate a still further uplift to the north and south, and the comparatively young topography along these scarps and within this valley proves that the final movement was, at earliest, middle to late Tertiary in age.

Coming on to the Ranchi plateau, standing at a general level of 2,000 feet, we find almost a perfect example of an old peneplain, with rivers on the plateau having almost base level appearances, but as they approach the edge the rivers suddenly steepen and form long precipitous narrow gorges. Decomposition of the gneissic rocks in these uplands had bitten deeply, here and there smooth rounded tors project, and there is every characteristic of a very old land surface. West and then north from here the country connects up with the plateau previously described south of the Son river. Here and there are residual ridges and, especially to the west, severely eroded residual plateaux, such as that of Neturhat, al stand at a general level of 3,000 feet and are all heavily cappel with laterite. They are clearly the remains of a still older peneplain.

Right at the extreme west these older 3,000 foot plateaux are of Deccan traps, so that the old land surface which these plateaux represent cannot be older than early Tertiary. This old early Tertiary peneplain was uplifted 1,000 feet and the new peneplain formed was practically completed down to base level before the next uplift commenced, necessitating a period of geological time extending at least into the latter half of the Tertiary.

This next uplift, of the Ranchi and Hazaribagh plateaux, gave rise to an abrupt scarp on the eastern side of the Ranchi plateau, although the movement to the north on the eastern and northern sides of the Hazaribagh plateau, is represented by a gradual tilt. Between the two plateaux the Gondwana basin was not uplifted to the same extent, particularly at the eastern end; adjustment presumably took place along the old boundary faults, so that the Gondwanas were left in the trough between the two plateaux and have thus been preserved.

The eastern edge of the Ranchi plateau, represented either by a fault or a steep upwarp, has been deeply dissected by long re-entrant valleys, and close to the edge small residuals of this mid-Tertiary peneplain are becoming isolated in the lower plain. From here east to the Gangetic alluvium the surface has a slight gradient, but is practically the mid-Tertiary peneplain at its old level; the streams are almost at base level once they leave the edge of the plateau.

South from the Ranchi plateau a hill country, showing quite a young topography, continues through the Eastern States towards the Madras Presidency. The general level of the hilltops is that of the Ranchi plateau, and this deeply dissected region represents a southerly continuation of that elevated mid-Tertiary peneplain. Occasionally higher hills and smaller plateaux, such as at Nimdih to the north of Chakradharpur, rise to 3,000 feet, and perhaps represent higher residuals from the early Tertiary peneplain.

From this dissected plateau region there is a more or less gradual and irregular descent to the coastal plains, but on their eastern side, close to the edge of the coastal plains proper, there is clear evidence of even a later uplift which has taken place subsequent to the deposition of coastal gravels of presumably late Tertiary age. Dunn has recently described (1933, pp. 285-286) the evidence for uplift in this region as provided by certain gravel-and laterite-capped small plateaux. The level of these plateaux is 850 feet above sea level, whilst that of the plains at the edge of the dissected Ranchi

plateau is 600 to 700 feet, but across the Subarnarekha river there is a sudden change in level to 250 to 350 feet at the base of the same gravels. Dr. Dunn has deduced from the evidence a general upwarp along the coast of 400 feet with an additional differential upwarp of 300 feet west of the Subarnarekha, giving a total of 700 feet. The differential uplift of 300 feet took place at an early stage, but the additional general coastal uplift of 400 feet has continued to the present day. The tendency of this uplift to steepen the gradients of the Subarnarekha and other rivers has been compensated by the seaward lengthening of the rivers as a result of deposition of sediments.

Summarising the foregoing discussion we have, in this part of India, the following sequence of uplifts :—

1. An early Tertiary peneplain, uplifted 1,000 feet to the south and with a tilt to the north-east. It is represented by the Neturhat and other plateaux, residuals above the present Ranchi plateau, whilst the Rajmahal hills are also representative of its north-eastern corner.

2. A further uplift of perhaps 1,000 feet sometime between middle and late Tertiary, reaching a maximum in the Ranchi plateau and its dissected extension to the south. This uplift was in the nature of a tilt to the north and north-east from the Hazaribagh plateau, but at the Son river the northern edge of the upwarp was more abrupt. On the eastern side the upwarp was also abrupt.

3. Further south, after an interval sufficient to permit the formation of quite a well-defined peneplain, a further uplift of 300 feet took place with at least a sharp upwarp in the Subarnarekha region.

4. A gradual further rise in the south and also along the east coast, amounting to 400 feet, down to the present day.

It is apparent, then, that the Tertiary period has been one of no inconsiderable movement in this part of the Peninsula, although not on the same scale as in the Himalaya. The type of movements in the two areas were vastly different, however, for on the Peninsula they were of the block type.

To the south of Chota Nagpur the upward movements were cumulative, whereas further north, close to the edge of the Gangetic alluvium, and particularly around the Rajmahal hills, there was no apparent differential movement—there may have been subsidence, but certainly not uplift.

These considerations are diagrammatically shown in fig. 15, in which the Rajmahal hills region is regarded as the hinge zone between the Gangetic down-warp and the Chota Nagpur upwarp.

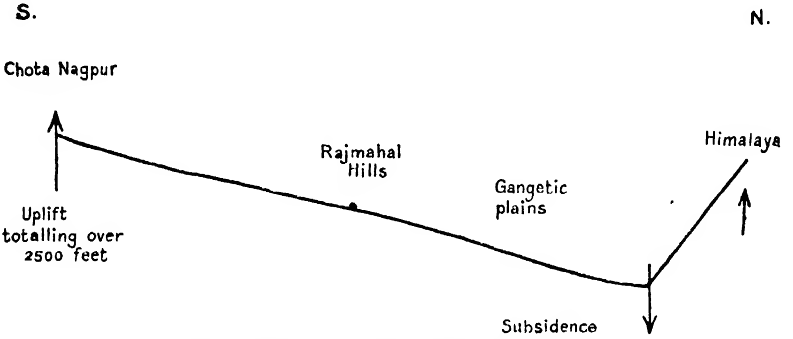

FIG. 15.—Diagram of sectional displacement in Bihar.

This section emphasizes the danger in laying too much stress on movements actually manifest in the Himalaya as the source of earthquakes in this part of India. The evidence of this part of the Peninsula indicates the influence of north-south compression from Tertiary to Recent times. This compression is presumably active where the peninsular gneisses are incorporated with the southern limit of the root of the Himalaya, and many of our earthquakes may be associated rather with the block movements within these gneisses than with the fold and thrust movements of the younger rocks.

CHAPTER IX.

SURFACE GEOLOGICAL STRUCTURES AND EARTHQUAKES.

(D. N. WADIA AND J. B. AUDEN.)

The Assam earthquake of 1897.

A fair amount of evidence has been collected within the last forty years concerning the relationship between visible geological structures and earthquakes.

The Assam earthquake of 1897 was described in the classic memoir of R. D. Oldham (1899), and a re-interpretation was made by him 27 years later of the manner of origin of the shock (1926).

> 'In the central area of the shock there was no master fault or fracture which could be regarded as the origin, but a large area over which the disturbance was everywhere great and in many places extreme. Throughout the greater part of the Garo and Khasia hills the intensity probably nowhere sank below VIII° of the Mercalli scale, more usually it reached fully X°, and in places even the XII° of the extension, proposed by Cancani, would have been inadequate as a measure of intensity. In this region there were repeated indications of the distortion of the ground, giving rise to changes of level, faults, and fractures, of the solid rock.
>
> The complexity of the disturbance and the existence of a network of fractures, each of which might be regarded as a local origin of shock, led to the suggestion that they were the secondary fractures and faults, resulting from a general movement along a thrust plane.'

There were difficulties, however, in the assumption that movement along a thrust-plane was the origin of the shock. The area of damage extended beyond the possible limits of the supposed thrust-plane. Moreover, there was a band of maximum disturbance which traversed the epicentral area from north to south just east of the 91° meridian, crossing all the great tectonic structures oblique to the strike :—the Garo hills, the Brahmaputra valley and penetrating even into the Himalaya. The existence of this band is held to be incompatible with localisation of the origin of the shock to a surface feature such as a thrust-plane. There is, in addition, no evidence that a thrust-plane of any magnitude occurs in the region of the Garo hills. Just south of Tura Dr. Fox noticed that the gneiss was overthrust upon the Eocene, but this appears to be a local feature (Fox, 1934, p. 77). Over the greater part of the

southern edge of the Garo hills there is only a monoclinal fold. There is, therefore, no geological evidence for the overthrust at one time postulated by Oldham. Quoting Oldham again (1926, p. 56) :—

'It is, therefore, not to tectonic processes, revealed by the surface rocks, that we can look for the ultimate cause of the earthquake; but rather it must be sought for in the region below the outer crust of the earth.

The distribution of extreme violence of shock was so localised, and in many cases so definitely related to fractures and displacements of the solid rock, as to leave no room for doubt that the two were closely connected, as cause and effect; but the elaborate and extensive system of fracture, and distortion, of the outer rocks, was itself the secondary result of a deep seated cause, which is shown, by the facts recited above, to be independent of the tectonic structure of the rocks exposed to observation.'

Oldham's final explanation is the occurrence of a bathyseism, a deep-seated impulse below the crust of the earth resulting probably from a violent and sudden expansion of magma. This expansion he considered as due to a process outlined by Fermor (1913, p. 41 and 1914, p. 65), in which a recombination of chemical constituents takes place with changes in molecular volumes.

The Kangra Valley earthquake.

With regard to the Kangra earthquake, Middlemiss came to the following main conclusions (1910, pp. 335-340) :—

(1) The two epicentres of Kangra and Rajpur are situated at points where the Tertiary rocks make re-entrants towards the central Himalaya. These two embayments—

'must have been places where special local conditions have offered a temporary resistance to the normal onward march of those regular waves of flexure.'

(2) The two epicentres lie approximately but not exactly along the line of the main boundary fault—

'... the position of the actual axial centrum, as derived from the isoseists, in the case of the Kangra area, was more nearly coincident with that of the reversed fault between the younger Siwalik conglomerate and the older sandstones than with the main boundary itself.'

We have already discussed (p. 122) the nomenclature of the main boundary fault. Middlemiss, at the time of writing his memoir, considered this fault as the plane separating the Tertiaries from the older Himalayan rocks, and not that dividing off the Siwaliks from the Murrees. In reality, however, the Kangra

epicentre does occur along the main boundary fault, as defined by Medlicott.[1] The Rajpur epicentre on the other hand, lies along the Krol thrust, the homology of which is at present uncertain, since it is not yet known to what extent the Murrees are present near Rajpur. If Murrees are absent, the Krol thrust will in fact be the main boundary fault. From the point of view of this memoir, the actual nomenclature is not of much importance, although it was thought advisable that the confusion arising in connection with it should be cleared up.

Returning to Middlemiss' conclusions, it is seen that there are two concepts involved :— first, the idea of a packing up of folds in response to resistance, presumably from the peninsular basement; second, the localisation of the earthquake movement near fault planes.

Recently, Auden, as a result of his work in the Dehra Dun area, has been led to doubt the significance of the first conclusion in so far as it concerns the Rajpur epicentre. There is little indication of a packing up or virgation of folds round the Dehra re-entrant. On the contrary, the folds preserve a general N.W.—S.E. trend, and are abruptly truncated by the re-entrant, which appears to be an erosional feature and not a syntaxis. There are admittedly changes in the directions of the fold axes between the Tons and Ganges rivers, but these changes are much less in magnitude than the actual deflection of the topographical ranges bordering the Dun.

The topographical embayment around Rajpur was regarded by Medlicott as a pre-Siwalik erosional feature, against which the Siwalik rocks were deposited. On this idea no deflection around a resistant basement would need in any case to be postulated. The absence of deflection does not, however, indicate that the conception of Medlicott is correct, for it is certain that the boundary between the Siwaliks and the pre-Tertiaries is in fact the Krol thrust. This thrust, although concealed by *dun* gravels over the greater part of Map No. 53 J/S. W., must make a right-angle bend around Rajpur and Kalanga hill, and must show considerable variation in direction of dip, from northwards near Rajpur to E. S. E. on the west side of Kalanga. While the pre-Tertiary rocks brought forward by this thrust do not appear to have been deflected or

[1] Middlemiss himself adopted Medlicott's usage in a later paper. *Rec. Geol. Surv. Ind.*, L, p. 122, (1919).

packed up to any marked extent around Rajpur, the surface upon which they travelled may well have been uneven, with an elevation in the vicinity of Dehra. If this be so, it is possible that additional strains have been set up where the thrust has been arched over this hypothetical obstacle. These strains, originating presumably as long ago as the Miocene (see p. 124), may have been accentuated by recent isostatic movements and have resulted in the liberation of elastic earthquake waves.

A similar change in direction of the Krol thrust occurs in the neighbourhood of Rikhikesh, a place which is not known to be particularly seismic, and it is probably unwise at present to emphasise the possible connection of seismic activity with deflections in thrust-planes.

Turning to the connection between the Kangra earthquake and the visible thrusts, it seems that movement probably occurred along the main boundary fault which crops out at the surface. The average depth of origin of the shock is regarded by Middlemiss to have been from 16 to 20 miles. It is difficult, however, to suppose that the thrust between the Siwaliks and the Murrees descends to that depth, since it is very probable that the faults and folds within the Tertiaries are for the most part superficial features confined to these rocks. We are led, therefore, to a similar conclusion to that of Oldham, that there must have been some deep-seated disturbance which was manifested at the surface by thrusts already in existence. There is a difficulty in this concept in that a disturbance at such a depth would not presumably be localised superficially by movement along a narrow zone nearly coincident with the reversed fault between the Murree series and the Siwaliks. Moreover, as Mr. West has recently indicated, if the earthquake had been due to movement along either of the two boundary faults, at a depth of 20 miles or more, the epicentre would have been many miles to the north of its actual position (1937, p. 20).

Burmese earthquakes.

Burma is of great interest in connection with the study of tectonic earthquakes. In a recent memoir Coggin Brown (1933, p. 133 and Plate 6) has discussed the bearing of geological conditions on the causes of recent Burmese earthquakes, and has shown that their epicentres are situated along a definite alignment running from Shwebo, just north of Mandalay, to Pegu, near Rangoon.

This alignment follows closely the railway line from Rangoon to Mandalay. Coggin Brown's conclusions are that the eight earthquakes which have occurred in Burma between 1929 and 1931 have their origin in the growth of a fault or faults lying in an unstable region at the foot of the Shan plateau. Moreover, there are considerable analogies between the structure of Burma and that of northern India. La Touche (1913, p. 357) has compared the Shan Plateau with that of Tibet; the fringe of Archean and Paleozoic rocks, which borders this plateau, with the Himalaya; and the zone of Tertiary rocks along the Irrawaddy with the Siwalik belt south of the Himalaya. The Burmese earthquakes have occurred along an unstable zone at the foot, and just west, of the Shan plateau in a manner comparable with the folded and faulted belt of Siwaliks and alluvium along the northern edge of the Gangetic valley.

Baluchistan earthquakes.

The Baluchistan earthquakes have been discussed recently by Mr. W. D. West [1935 (2), p. 200], who has collected information concerning the earthquakes which have occurred in Baluchistan during the last century of sufficient intensity to cause damage to buildings. He has shown that the epicentres are grouped around the pronounced re-entrant at the northern end of which Quetta is situated. In this re-entrant there is a packing of folds as if these had been caught up by some projection in the peninsular basement at the time of the Tertiary orogenesis. West has also shown that none of the known faults had any connection with the origin of the Quetta earthquake of the 31st May, 1935. He concludes by saying (p. 222) :—

'Whatever the exact origin may have been, however, it seems likely to have been connected with the strain which must exist at the head of this re-entrant angle, a strain which can have been relieved only locally by the present earthquake.'

The relationship is similar to that envisaged by Middlemiss, though in the case of the Kangra earthquake, the packing up of folds is far less pronounced, being absent altogether from the Rajpur epicentre.

Bihar-Nepal earthquake.

We have seen that in the case of the Bihar-Nepal earthquake there were three areas of maximum damage corresponding to X or

more of the Mercalli scale:—the Nepal valley; between Sitamarhi and Madhubani; and at Monghyr. The Nepal valley lies within the Himalaya. The main epicentral region is entirely upon alluvium. Monghyr lies at the junction of the alluvium and the Peninsula. All three geological units appear to be involved in this earthquake, whereas, superficially at any rate, the Baluchistan and Kangra earthquakes were connected only with the Tertiary mountain chains. The nearest parallel to the Bihar-Nepal earthquake is that of Assam in 1897. It is probable, however, that the peninsular basement is involved also in the Kangra and Baluchistan earthquakes and that the apparent distinctions are not in reality very significant.

It is obvious that there can be no question of the Bihar-Nepal earthquake being connected with any re-entrant in the Himalaya. It occurred where the arcuate disposition of the mountains is most pronounced.

With regard to Himalayan faults, the structure of the Nepalese mountains is in essence similar to that of the Himalayan foothills between Dehra and Kathgodam. A thrust separates the Nahans from the underlying upper Siwalik conglomerates both at Hitaura (27° 26′ : 85° 02′) and near Nepaltar (26° 54′ : 86° 32′). The so-called main boundary fault, which is almost certainly a continuation to the south-east of the Krol thrust, is found just north of Sanotar (27° 28′ : 85° 02′), on the first col E.N.E. of Udaipur Garhi (26° 57′ : 86° 32′) and probably runs through Dharan Bazar (26° 49′ : 87° 17′) to pass below Tindharia on the Darjeeling-Himalayan railway. Another thrust occurs 1·6 miles E.N.E. of Udaipur Garhi, and marks the boundary between the metamorphics and the underlying possibly Krol rocks. Auden believes that this thrust may be the same as the Garhwal thrust of the Dehra Dun area. A section is given in *Records, Geological Survey of India*, Vol. 69, p. 146.

The Nepal valley lies to the north of all these faults, while the epicentral region and the area within isoseist IX between Patna and Monghyr lie to the south.

Intense damage in the Nepal valley seems to have been confined to structures built upon the Pleistocene gravels and recent alluvium, and was far less severe, and sometimes even negligible, on actual rock outcrops. The little that is known about the geology of the Nepal valley has been described by Auden in *Records, Geological*

Survey of India, Vol. 69, pp. 140-152. The E.N.E.—W.S.W. strike of the X isoseist in the valley is strongly inclined to the general W.N.W.—E.S.E. strike of the Himalaya in this region, and, failing direct geological evidence which can only be produced by detailed mapping, we see no reason to postulate a fault below the alignment of the isoseist which would be so oblique to the strike. It seems likely that, had there been no alluvial basin, the damage in the valley would have been no more intense than that at Darjeeling, and that it is not necessary to look for local undiscovered faults as an explanation of the increased severity. We prefer to regard the region of the Himalaya within isoseist VIII, stretching from just west of Katmandu as far as Darjeeling, as structurally equally involved in the earthquake.

We come next to the epicentral region between Sitamarhi and east of Madhubani. On Plate 2 the isoseismal lines are shown in red for the whole of India, while the heavy black broken line represents the course of the main boundary fault. The area enclosed by isoseismal X lies some 50 miles from the main boundary fault, and 38 miles or so from the nearest outcrop of the Siwalik rocks.

While the damage to Udaipur Garhi and Dharan is certainly great, it cannot be stated that the intensity at these places bears any definite relationship to the boundary fault or thrust plane. No signs of movement were seen along the thrust plane where it is exposed near Udaipur Garhi. The houses at Udaipur Garhi and Dharan, being of very unstable construction, have naturally collapsed more than the bamboo mud huts of the villages in the plains just below. Rock falls are not confined to the vicinity of the thrust-plane, but scar the hill sides around Udaipur Garhi for miles to north and south. Whatever movement may have occurred along this thrust-plane below the surface, nothing remarkable happened at its outcrop. It is more probable that the movements responsible for the earthquake originated further south, along a fault zone that is now concealed by the Gangetic alluvium.

The significance of the slump belt, and of the area of apparent subsidence determined by the Survey of India is almost certainly that the alluvium there has received a most severe shaking as a result of lying immediately above the main zone of disturbance.

The surface characteristics of the slump belt, while an indication of the location of the focal region, do not, however, afford information

concerning the nature of the fracture below the alluvium, which was responsible for the earthquake. The earth fissures which were observed were purely superficial effects in the alluvium, a consequence of its incoherent nature. Hence, conclusions drawn from a surface examination as to the nature of the underlying fracture or fractures must be hypothetical.

The elongated trend of the isoseismal ellipses strongly suggests the linear nature of the centrum or focal region, and the occurrence of one or more fractures below the Gangetic alluvium between Motihari and Purnea may, with some certainty, be postulated.

From the parallelism of the major axis of the ellipse of isoseismal X, between Sitamarhi and Madhubani, and of the larger slump belt between Motihari and Purnea, with the zone of thrusts in the Himalaya, it is possible to infer that the zone of fractures may continue eastwards, still parallel to the Himalaya, as far as Dhubri in Assam. Dhubri, as is well known, is situated in a highly unstable area (Gee, 1934). Westwards, this fracture zone probably dies out against the north-eastward continuation of the Aravalli range (Delhi ridge) below the Gangetic alluvium, though, from the rapid fading in intensity of the shock to the W.N.W. of Motihari, it is evident that considerable movement along this zone was confined during the last earthquake to Bihar.

We considered on page 137 that any thrusts or folds existing in the Siwaliks below the alluvium are likely to be superficial, and not to penetrate far into the basement. The recent geophysical survey carried out in Bihar shows an abrupt change in the gradient of the boundary surface between the alluvium and the basement (Glennie, 1935, p. 59). We believe that this boundary surface is probably one separating the combined alluvium and Siwaliks from the basement, but this does not affect the argument.

Colonel Glennie writes :—

'A final interpretation is not possible from a single traverse line of this nature. The figure below is consistent with the results. It may be supposed that there has been a southerly movement of a concealed thrust fault just south of the Nepal boundary, and that the feature just south of Motihari has opposed southerly movement in the lower layers of the alluvium, so that there is an enhancement of surface effects in this region. If this is correct then the same feature should screen the areas further south.........................

This evidence then is strongly in favour of screening by the feature south of Motihari.'

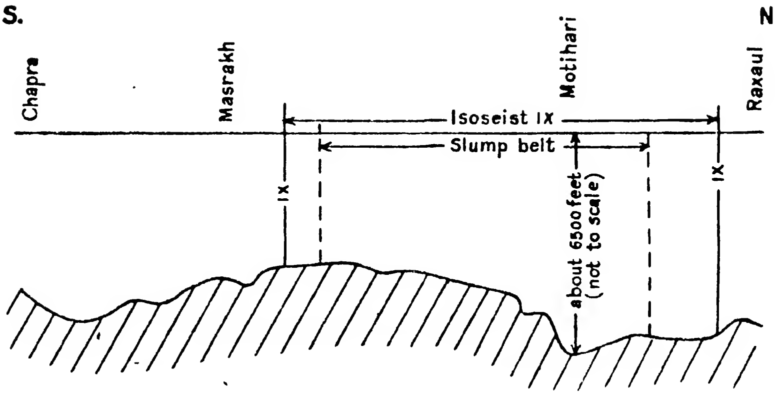

FIG. 16.—Sub-alluvial profile across North Bihar, according to E. A. Glennie.

It will be noticed that Colonel Glennie assumes the existence of a thrust fault just south of the Nepal boundary, *i.e.*, below Raxaul, and that the bluff below Motihari has prevented the lower layers of the alluvium from moving southwards. It is difficult to see the reason for these assumptions. Firstly, there is nothing in the section figured above to suggest which of the changes in gradient corresponds to the postulated thrust fault. Secondly, if the thrust fault dips to the north, the underthrust portion (south of Raxaul) may be supposed to have been moved northwards relative to the overthrust northern block. In this case the bluff in the basement below Motihari, instead of opposing southerly movement of the lower layers of the alluvium and Siwaliks, would act as a buttress favouring the northward movement of these lower alluvial layers below the thrust-plane. It is not supposed by us that the alluvium and Siwaliks were involved in any extensive lateral movement. In the case of earthquakes in which a correlation has been possible between the distribution of isoseismals and the location of faults, the actual movement recorded along these faults is very slight indeed, rarely exceeding a few inches or at most a few feet, both along the vertical and horizontal directions.

The section given by the Survey of India might equally be held to imply a fault scarp below Motihari, where, from surface indications, we had previously been led to postulate one. It cannot be supposed, however, that the geophysical results have confirmed

our postulated fault zone, because the section obtained from this evidence is capable of a number of interpretations.

Finally, we should consider the areas within isoseismals IX and X between Patna and Monghyr. The IX isoseismal is elongated and narrow, and for most of its course lies just south of the Ganges. The area within this isoseismal does not, however, follow the river precisely, but crosses the north salients. Proximity to the banks of the Ganges may be a partial explanation, but it may still be necessary to assume a fault zone below this area.

The violence of damage at Monghyr is almost certainly related to its situation on very thin alluvium immediately adjacent to the Archean rocks of the Peninsula. Such a situation is well known to be liable to excessive damage. It was recognised by Mallet in his report in 1850 to the British Association on the great Calabrian earthquake, and has been observed in the case of more recent earthquakes. Freeman states as follows (1932, p. 367) :—

'The localities most disturbed of all by an earthquake will be found in the narrow zone along the dividing lines between hard ground and soft ground. As in the case of a semifluid material in a bowl set into vibration, the waves will be found highest against the rigid wall of the basin, at the outer edge of the soft material................

'In San Francisco, a few of the zones of maximum violence and damage were found on the soft ground near the rigid rim of a bed-rock basin containing wet unconsolidated sediments.'

It is suitable here to discuss a note written by Professor Nobuji Nasu, as a result of his visit to Bihar in 1934. Professor Nasu considers that a focal line or plane cannot exist in reality, and concludes from his experience of the Japanese earthquakes that the Bihar-Nepal earthquake cannot be attributed to compressional movement or the push of the Himalayan mass upon thrust faults. Nasu's conclusions were that sudden changes in bulk occurred in the mass underlying the Himalaya which resulted in the bending and fracture of the crust, causing jerky movements along the main boundary fault. Nasu considers that there are zones of particularly weak strata along the Motihari-Purnea and the Muzaffarpur-Darbhanga belts, and that the linear distribution of earthquake damage is due to these zones of soft and weak alluvium and not to any linear nature of the seismic origin. He cites the Saitana earthquake of 1931 in Japan, in which the epicentre of the shock was found to be in the hilly region of Titibu, while the zone of maximum damage was limited to a narrow region bordering the river Tone.

In our opinion, the main boundary fault was inactive during the earthquake. We believe that the distribution of isoseismals and of the slump belt is such as to indicate a fault zone between Motihari and Purnea. The seismological evidence definitely indicates that the origin lies in the plains of Bihar and Nepal, and not in the mass of the Himalaya.

With regard to the question of zones of weak alluvium, it seems improbable, without definite evidence from a large number of borehole records, that the distribution of the alluvial facies occurs along east-west zones. The upper layers of the alluvium of North Bihar have been laid down by rivers flowing in general from north-west to south-east, and the variation in facies is likely to be aligned along zones roughly parallel to this direction. The Kosi, for instance, has laid down a wide belt of sand which runs in a north-south direction. The courses of the rivers are certainly not constant, but their general trend is likely to have been towards the south-east. Wind, also, is a modifying factor. But the dominant wind is from the west and we do not suppose that narrow zones of weak strata would have been re-deposited along an east-west strike by a west wind.

It appears to us therefore that the alignment of isoseismals does in fact indicate a linear zone of disturbance for the shock as manifested in the crust, and not a line of comparatively weak strata.

A further point should be noticed. It was mentioned in a previous chapter (p. 87) that over the greater part of the area, particularly south of the Ganges, the directions of fall of objects were east-west. In the central region the direction was more often N.N.E.-S.S.W. So far as could be seen, there was no tendency for objects to fall towards a central point or even a central line. The conclusion which may be drawn from this is, probably, that movement involved considerable areas of the outer crust, and took place for the most part horizontally in a general east-west direction, parallel to the postulated fracture zone, in a manner comparable to that which occurred along the San Andreas rift in the San Francisco earthquake of 1906.

When we consider the conclusions drawn from an examination of the seismograms, we find that the major shock is located in a more circumscribed area around lat. 26° 21′ N. and long. 86° 12′ E. and that the depth of origin is about 14·8 kms. or 9·2 miles. It

is here that we are brought up against the main difficulty, one which is apparent in so many earthquakes, namely that the actual origin of the shock lies at a depth and is generally localised, while the manifestation of the shock in the upper layers of the crust often lies along an extended zone. In the concluding section we will attempt to discuss the question of bathyseisms, already mentioned in the case of the Assam earthquake, and the relation of earthquakes to gravity anomalies.

Shortly after the Bihar-Nepal earthquake, Dr. J. de Graaff Hunter published an article in *Nature* in which he brought out the relationship between the epicentral area and a region of underload (1934, p. 236). The centre of this region of underload lies between Motihari and Gorakhpur, and although slightly west of the epicentral area, the long axis of the ellipse of underload contours coincides with that of the X isoseismal and slump belt. His figure is reproduced in text fig. 17 with slight modification.

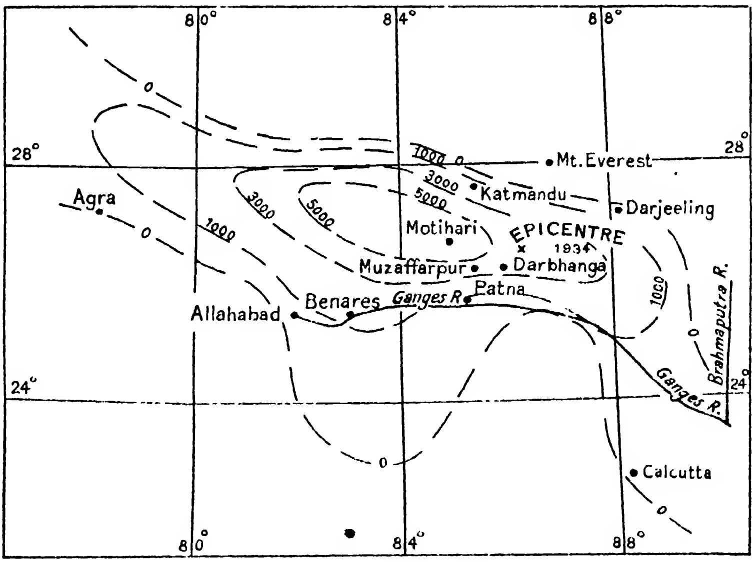

FIG. 17.—Underloading in North Bihar.

Graaff Hunter states :—

'The average underloading of this area of about 100,000 square miles is on an average equivalent to a thickness of rock of more than 3,000 feet; or, put

otherwise, the deficiency of pressure in the crust is above 200 tons per square foot. This underloading arises from abnormally low densities in the crust. It is in part accounted for by the low density of the alluvium of the Ganges valley ; but unless this alluvium extends to a greater depth than most geologists would believe, the explanation is not wholly there........

These regions of great loading anomaly must cause very great stress-differences in the earth's crust which supports them. The region of underload and the amount of underloading are very much of the order which has been estimated by Dr. H. Jeffreys to be sufficient to cause fracture in the lithosphere.'

In our preliminary report we suggested that geologists were willing to allow a thickness of alluvium up to 15,000 feet, a figure adopted by R. D. Oldham in a passage already quoted on page 134. As stated on page 135, recent work by the Survey of India indicates that the probable thickness of the alluvium is less. Glennie estimated in 1932 a thickness of 6,500 feet, which probably applies to the alluvium and Siwaliks together. The situation is now reversed, for the geodesists require a smaller thickness than that previously suggested by the geologists. But, whether the thickness is 15,000 feet, or only 6,500 feet, it seems certain, as Glennie has indicated, that the light alluvial sediments will not alone explain the negative anomalies. He considers that the cause of these anomalies in the plains of North Bihar is to be sought in deep-seated depressions in the granitic and underlying shells of the crust (Glennie, 1932).

Glennie has continued this thesis of the association of seismic areas with downwarps and underloading. In the case of the Quetta earthquake of 1935 he states (1935, p. 49) :—

'A narrow downwarp appears to run west of Jaisalmer to the Rann of Cutch, the Gulf of Cutch being associated with this ; then there is an upwarp running from Karachi to Jacobabad ; while to the west and north of this the main downwarp occurs. The boundary fault and igneous formations further west indicate an upwarp. The epicentre of the recent Quetta earthquake appears to have been over the deepest part of the downwarp which is evidently being still further narrowed and deepened. The warp anomalies therefore show very clearly the nature of this event. The negative anomaly at Quetta (-39 mgals) indicates a depth of downwarp of about 11,000 feet.'

This belief in the association of seismic activity with downwarps and negative anomalies is confirmed by the locations of the epicentres of the Bihar earthquake and of the main region of the Kangra earthquake. It is less certain, however, that either the Assam earthquake of 1897, or the Cutch earthquake of 1819, were connected with marked downwarping and negative anomalies. Further,

there is a region of strong negative anomalies in south-west India that is seismically inactive.

Meinesz has suggested that there is coincidence between the belt of negative anomalies in the Dutch East Indies and the clustering of earthquake epicentra, maintaining that the mass defect is related to tectonic activity in the Archipelago (1934, p. 118). A careful examination of Plate IV and fig. 26 of his book shows, however, that many of the epicentra are located in regions of high positive anomaly, and that the relationship asserted by Meinesz is not very close.

Both in the east Ferghana and east Tadjikstan regions, and in Fennoscandia, the seismically active areas have been shown recently by Mushketov (1936, pp. 477, 479) to be located where the anomalies are negative and the crust is in the process of epeirogenetic uplift.

We have seen that the seismic belt of northern India is situated north of the Peninsula in Assam and along the Indo-Gangetic alluvium and the bordering mountains. The evidence for recent uplift in the Himalaya and that part of the Peninsula immediately to the south of the Bihar seismic zone, is clear, and has already been given (pages 125-131, 137-142). From the incomplete geodetic data available, the Himalaya appears to be a region of positive anomalies, in spite of the great thickness of sedimentary rocks present (20,000 feet for the Krol syncline, and at least 17,000 feet for the Tethys syncline). Graaff Hunter has also suggested that the negative region of North Bihar has been subject to a secular regional uplift, but this suggestion has not been confirmed by the most recent examination of the levelling data (1934, p. 236) and has been abandoned by the Survey of India. The accumulation of 6,500 feet (certainly a minimum figure) of light fluviatile sediments in a basin, the upper surface of which does not rise more than 900 feet above sea level, implies downwarping of the basement. Indeed, if any considerable uplift had taken place in the Gangetic plain, the meandering rivers should be incised to a deeper extent than they are. The whole trend of geological evidence regards the plain as still an area of downwarp, not yet subjected to isostatic adjustment by elevation. There is, therefore, a zone of uplift throughout the Himalaya, a zone that is probably still being depressed to the south, and a zone of uplift further south again, on the Peninsula. The maximum differential move-

ments, as pointed out on page 142, is between the northern part of the Gangetic plains and the Himalaya. The zone lying just to the south of the Siwalik ranges, must be subject to great strain, and we may expect sudden relief along fractures as a result of more deep-seated disturbances. As suggested in our Preliminary Report, we consider that the underload in North Bihar is to be regarded not as the cause of the earthquake, but rather as a consequence of the tectonic processes in that region which have resulted also in downwarping and fracturing (Auden and Ghosh, 1934, p. 222). From the examples mentioned just above, it seems that the association between seismic instability and negative anomalies is not invariable, and that both regions of downwarp and of upwarp may be seismically active.

The epicentre of the first main shock as calculated by Dr. Roy is some eight miles east of Madhubani, at lat. 26° 21′ N : long. 86° 12′ E, while the depth of origin is considered by him to lie about 14·8 km. or 9·2 miles. This lies within the limits of the sub-alluvial trace of the postulated fracture zone, from which it may be concluded that the inclination of the fracture through the granitic crust is steep. In such an extensive fault region as is suggested here, the terms 'focus' and 'depth of origin' may be taken to apply to the point from which the fracturing actually first began, before quickly extending to the whole of the fracture plane.

The evidence leads us therefore to two conclusions. Firstly, a condition of strain between the uprising Himalaya and the downwarped alluvial belt. Secondly, it appears from the direction of fall of objects that the actual movement responsible for the shock may have been largely horizontal, in an east-west direction. It would seem, therefore, that there may have been a considerable east-west component in the movements which resulted from the sudden relief of strain in the transitional zone between the Himalaya and the Gangetic plain.

It is not proposed to enter into a discussion of the ultimate cause of deep-seated earthquakes. We referred on page 114 to Oldham's idea that the Assam earthquake was the result of a bathyseism; this idea followed a conception advanced by Fermor. Fermor (1913, p. 41, 1914, p. 65) had pictured an infraplutonic shell of eclogite at an unknown depth, and that relief to pressure following tectonic movements would permit liquefaction of the eclogite in

this shell to basalt magma. This sudden expansion was suggested as the underlying cause of earthquakes. The suggestion is based entirely on speculation without any accompanying evidence. Indeed, in large earthquakes with shallow focus, such as the Bihar earthquake, such tectonic movements as would permit liquefaction of the eclogite may, themselves, well be the origin of the seismic waves. It is believed by some of us that enough attention has not as yet been paid to certain of the known effects of stresses in bodies, in which speculation of change of state and of volume need play no part. Dr. Dunn has suggested as a line of thought that fractures might arise as the ultimate result of alternating stresses due, for example, to tidal stress at the irregular interfaces of different rocks in deep-seated parts of the crust; the effects would be comparable with the so-called fatigue cracks formed as a result of alternating stress in materials.

The subject of the various ultimate causes of earthquakes is much too conjectional to pursue further here.

Summary.

We have briefly traced the history of the formation of Northern India during the Tertiary and Quaternary eras and the structure of its framework. There is evidence for great horizontal movements along thrust-planes in the Himalaya and of recent downwarp in the great basin at its foot, together with upwarps further south in the Peninsula. The movements in the Himalaya probably reached their maximum extent during the Miocene, but we have seen evidence of their continued activity till the end of the middle Pleistocene. The highest of these Himalayan thrusts are now so dissected by erosion that they may be considered inert and as having little, if any, connection with modern seismic phenomena. There is also evidence of movement along the less dissected portions of the lower thrusts in the Himalaya during the Miocene and Pliocene, and of Pleistocene thrusts within the Siwaliks and Older Alluvium. The Karewa alluvium of Kashmir gives clear evidence of an uplift of the mountains of several thousand feet during the Pleistocene. In addition, the terraces and profiles of Himalayan rivers indicate very recent vertical uplift.

The evidence therefore for recent instability in the Himalaya is very strong. In North Bihar we have indicated uplift to the

south of the epicentral region aggregating over 2,500 feet during Tertiary times. This uplift gave rise to a general tilting towards the north hinging about the Rajmahal hills, north of which there was subsidence to an extent of which we are not certain.

There is little doubt that the two types of movements are effects of the same underlying tectonic cause.

As has been stated previously, the origin of the Bihar earthquake, as determined both from the field investigations of the Geological Survey and from an examination of the seismograms, does not lie in the Himalaya, but below the Gangetic alluvium. Geodetic evidence indicates that the Gangetic plain of North Bihar is a downwarp, a synclinal depression, and that the negative anomalies present in the area are due largely to the depression of the granitic and underlying basic layers of the crust and to a minor extent to the presence of a considerable thickness of light alluvial sediments, of specific gravity less than that of normal rock, filling the depression.

Geological evidence also suggests that the downwarped Gangetic basin has not yet begun to rise and become isostatically adjusted.

The uplift of the Himalaya and Peninsula and the depression of the Gangetic basin should all be regarded as related, and the location of the origin of the shock in the depressed zone is significant. It is in this zone that a state of strain or potential fracture must be presumed to exist.

The position of the slump belt suggests the existence below the alluvium of a zone of fracture, extending from Motihari to Purnea and possibly continuing to Dhubri in Assam. The geophysical work recently carried out by the Survey of India indicates many pronounced irregularities in the basement of the alluvium (or the alluvium and Siwaliks combined) and it is possible that the sudden changes in gradient below Motihari and Raxaul may correspond to faults which were in movement during the earthquake. More data are required, however, before a proper correlation between sub-alluvial contours and the surface earthquake effects is possible.

We do not favour the opinion put forward by Dr. Nasu that the shock originated beneath the Himalaya, and that the formation of the slump belt was due to a zone of particularly weak sediments lying to the south. There is no evidence that the sediments of the slump belt differ from those of the alluvium to the north and south of it.

Movement along the fracture zone between Motihari and Purnea probably had a considerable component in an east-west direction. This fracture zone is considered as being responsible for the earthquake. The high isoseismals of the Nepal valley are regarded as a consequence of the young alluvial sediments present in the valley, which, though not water-logged as in the case of the Gangetic alluvium, have markedly different elastic properties from the surrounding and harder pre-Tertiary rocks. The narrow belt of high intensity between Patna and Monghyr has received no satisfactory explanation, but it is possible that there may be a subsidiary fault below this zone.

CHAPTER X.

ADVISORY OBSERVATIONS ON RECONSTRUCTION.[1]

(J. A. DUNN.)

Early views.

One of the principal objects of the survey party in North Bihar was to make certain recommendations as speedily as possible in order to assist Government's plans for future reconstruction. The following extract from a letter, dated Patna the 29th January, 1934, written by Dr. J. A. Dunn to the Chief Secretary to the Government of Bihar and Orissa, indicates our views at the commencement of the investigation :—

'Although it is unlikely that an earthquake of such intensity as that of the 15th January 1934 will be repeated within the same epicentre in the near future, there can be no assurance that minor tremors resulting from slight local adjustments may not take place......................

'Although these later minor tremors are unlikely to cause loss of life or further damage to present buildings, they may disturb any pucca buildings in course of erection, in which cement, mortar, etc., has not completely set.

'During the main earthquake the alluvium over the Gangetic plain was seriously fissured ; in places sand from along the fissures was ejected. Many of these cracks are small and escape detection, but minor tremors may cause slight movement along them, sufficient to crack the foundations of newly erected pucca buildings. This may take place particularly during the Monsoon when the ground becomes saturated. Even prior to the earthquake the soft alluvium forming the foundation of buildings throughout the Gangetic plain was by no means ideal.

'These considerations apply also to structures in hill country where seepage from the Monsoon rains may find its way along new fractures and lines of weakness causing landslides.

'Taking all the factors into consideration I would not advise haste in the reconstruction of pucca buildings. Wherever possible commencement of rebuilding should be deferred until after the next Monsoon. These remarks of course do not apply to repairs which could be undertaken immediately.'

We also issued the general warning that only light inexpensive buildings should be erected in the alluvial tract before the end of 1934. There was no excuse, accordingly, for the erection of unsuitable structures in this area on the plea of haste in rebuilding. The advice was justified as certain adjustments of the alluvium did eventually take place in several localities during the ensuing Monsoon.

[1] Much of this chapter has been taken, with some re-arrangement, from earlier reports of the authors.

Belts of lesser and greater disturbance.

It is becoming apparent that, in any earthquake, certain localities are more susceptible to the shock than adjacent localities. The reason is not entirely connected with the type of sub-soil, although this is apparently one of the factors determining the intensity of damage at any point; buildings erected over water-logged sands are more liable to damage than those on more compact ground. Other factors which we have not yet appreciated are certainly of importance, but our knowledge of this earthquake region of North India is too scanty as yet for us to form any definite reliable views.

The primary epicentral region of the 1934 earthquake was between Sitamarhi and Madhubani, but there were subsidiary areas of equally high intensity in the Nepal valley and at Monghyr; zones of less destruction (earthquake shadows) separated these areas of great damage. A similar disposition of intensities is suggested by the imperfect accounts of the 1833 disaster, but this evidence supplies no *primâ facie* case for supposing that the distribution of intensities will be identical in future shocks. So far, the evidence suggests that there is a fracture zone below the Motihari-Purnea belt and this may continue to the east towards Dhubri, and perhaps further east up the Brahmaputra valley. It is possible that another fracture zone occurs along the Patna-Monghyr line; Monghyr is known to suffer from shocks more than any other place south of the Ganges, but this may be explained equally as well by the position of the town close to the junction of the alluvium and Archean basement as by the existence of underlying fractures.

It cannot be asserted that the lower intensity area between the Motihari-Purnea and the Patna-Monghyr zones will necessarily be more immune from shocks in the future until several further violent earthquakes have occurred and some constancy in the position of the isoseismals is established. As far as is known, another earthquake of even greater violence might result in this intervening area being included within isoseismal IX.

If the isoseismal maps of several of the comparatively recent shocks in the eastern part of Northern India are examined, it is found that certain localities have escaped the effects of severe shocks although areas on all sides may have been damaged at some time or other. It would be unwise at this stage, however,

to regard such localities as being peculiarly immune in the future. It is safer to accept the whole region between the Himalaya and a line along the Ganges through Patna in Bihar and Malda in Bengal and east to the Chittagong hill tracts as being particularly liable to shocks, and that no zones in it can as yet be delineated as less susceptible to damage. This region forms part of a belt of country across northern India, from Baluchistan to Burma, in which the damage resulting from earthquakes is likely to be severe (Plate 5 based on a map by J. B. Auden in 1935).

The problem is different in the Nepal valley, for here we have a small circumscribed area with marked contrasts in ground conditions. The information with regard to the 1833 earthquake in this valley is quite accurate and the coincidence in the isoseismal lines for that and the recent shock is close. It is apparent that clear lines of demarcation may be drawn in the Nepal valley between relatively stable and unstable areas. The tract between Bhatgaon, Harisidhi, Khokna and Bagmati, included within isoseismal X, may be considered as peculiarly susceptible to the effects of future shocks. The area between Pashupatinath, Boddhanath and Gokarna is probably the safest in the valley.

Change of official headquarters sites.

The discussion in the last section leads logically to the question of localisation of official headquarters. This general question could not be discussed lightly after the earthquake as many projects for the change in site of administrative centres were advanced. After careful consideration it seemed to us unnecessary that any drastic steps should be taken for the long distance removal of headquarters sites, except in the case of Madhipura. It was obvious, however, that expensive administrative buildings should not be erected on badly fissured sites, nor in the close vicinity of such large depressions as rivers or lakes, but apart from these considerations the headquarters should remain as close as possible to their original positions. Over considerable areas in Bihar there is some uniformity of sub-soil, and the evidence to date respecting earthquake shadows being unreliable, there was nothing to be gained by moving official headquarters many miles from their present sites.

At Motihari the two lakes had been the principal cause of the close fissuring of neighbouring ground and the destruction of buildings. It was apparent that new buildings should be kept away

from the vicinity of these lakes. On the immediate site of the old headquarters there were no unfissured areas of sufficient size to contain the proposed buildings. Accordingly Government decided to erect the administrative buildings at Luathaha, some 3½ miles away, and which was the nearest place in which the ground was relatively unfissured.

At Sitamarhi the old headquarters was on a very confined site along the river bank, and it was closely fissured. The only building which escaped relatively undamaged was the P. W. D. Inspection Bungalow, situated at some distance from the river. As Sitamarhi is a small headquarters station it seemed to us that very light structures might suitably be erected in the vicinity of the old site, otherwise we recommended construction upon adjacent ground away from the river. Government eventually decided to erect the administrative buildings about 2½ miles away at Dumra.

At Madhubani sufficient unfissured ground was found available on which to erect most of the administrative buildings close to their old sites, but the jail, hospital and a few residences were re-erected half a mile away.

Madhipura was the one town which it appeared advisable to abandon. Forty years ago, before the Kosi river had altered its course towards the vicinity of Madhipura, the town was an ideal site in every way. The many branches of the river have since made movement about the subdivision increasingly difficult, and during the rains the whole of the surrounding country is flooded, with the result that Madhipura during that season of the year can only be approached by boat. In addition, a branch of the Kosi east of the town was gradually working west and the protecting *band* (levee bank), which was damaged by the earthquake, was immediately breached and a large section removed by the river. There was little point in continuing the unequal fight with the river now that the site had become also administratively unsuitable.

The Geological Survey was approached more particularly as to the advisability of removing the headquarters of Purnea district. The advantages of the old site are obvious: it is central and easily accessible from any part of the district by roads and railways radiating from the town; there is also a settled community largely dependent upon the presence of the district headquarters, and vested interests would obviously suffer a grave loss were the head-

quarters to be removed. The disadvantages were: the ground around the civil headquarters had slumped somewhat; the locality is within the principal zone of weakness of the earthquake area and may be affected therefore by future tremors; the loose sandy nature of the ground is unsuitable for such massive buildings as have been erected.

Although Purnea is on the zone of weakness it must be remembered that in contrast to the damage in the civil lines the old town across the river was scarcely affected. The main reason for this is that the buildings in the old town are of much lighter construction and accordingly have not suffered subsidence. So far as the subsoil is concerned, there is no change for many miles around. Purnea is at the centre of a tract of country extending from the Nepal border to the Ganges and from the Kosi river to Kishanganj and which is formed of a sand bed 60-80 feet in depth in places.

If an alternative site had been necessary it would have to be found between Purnea and Araria, Purnea and Kishanganj, or Purnea and Katihar. Between Purnea and Araria the intensity of damage was equally as great as in Purnea. Between Purnea and Kishanganj the damage from six miles east of Purnea was negligible, but a future earthquake along an easterly continuation of the Motihari-Purnea fracture zone and extending towards the epicentre of the 1897 earthquake might give rise to damage at Kishanganj as severe as at Purnea. Between Purnea and Katihar the damage was slight and, from the point of view of future earthquake effects, Katihar would be the most suitable alternative site.

The advantages of Purnea, however, easily outweigh the doubtful geological gain in moving to Katihar. The civil lines cover a large area, the buildings being widely separated, and no one site could be regarded as more reliable than another. There was plenty of unfissured ground available in the town on which buildings lighter than previously could be erected.

It is apparent that these few slight changes in position of civil headquarters sites have been made not from the point of view of ultimate suitability for future earthquakes (apart from keeping buildings away from the vicinity of lakes, rivers, etc.) but simply for the purpose of immediate safety in construction. If unsuitable buildings are erected on these undamaged sites they are equally liable to destruction in future earthquakes. Heavy buildings will

themselves give rise to adjacent fissures in future shocks as in 1934, hence single storey light structures should be preferred wherever possible; otherwise special precautions should be taken in the construction of expensive foundations. The areal extent of buildings should be kept at a minimum, individual buildings, each covering a smaller area, are preferred to single large buildings containing many official departments.

In concluding this section we would suggest that, in future, where wide choice of sites is available for the erection of considerable structures of any project, some use be made of the evidence collected subsequent to the 1934 earthquake. We have pointed out the presence of "earthquake shadows"; whether such are likely to persist in future earthquakes remains to be seen, and we cannot guarantee them, but at least advantage might be taken of these localities with the view that at any rate they cannot be worse than other sites and there is the strong possibility that they might be considerably safer.

Building design.

From both a scientific and engineering viewpoint the whole of Northern India within, say, two hundred miles of the foothills of the Himalaya must be regarded as a region particularly susceptible to severe earthquakes. It has been repeatedly urged by the Geological Survey that the design of structures in this area should be controlled by legislation as it is in Japan and New Zealand. The remark has often been made that in Bihar, for example, one hundred years have elapsed since the previous severe earthquake and that legislation is scarcely necessary for such rare calamities. However, shocks are felt much more frequently than this in certain localities, particularly in eastern Bihar, and it should also be remembered that there is no real periodicity for such major earthquakes. No prediction can be made at this stage as to their future frequency. It is also often remarked that earthquake-proof buildings are particularly expensive, but this is not entirely correct. Simplicity in design and ornamentation is one of the earmarks of suitable buildings in an earthquake region; much can be done in the reduction of damage to buildings and in loss of life, by eliminating such of the expensive ornamentation as is of doubtful æsthetic value. Much could also be done by legislation in controlling the height

of buildings and the width of streets. Control in the actual design of buildings from foundation to roof need apply only to the more expensive kind of public building or factory.

It has been said that well-constructed buildings of brick came through the earthquake with but slight damage. This is only partly true and includes only single storey buildings of comparatively recent construction away from the vicinity of depressions where there was little or no slumping of the ground. The older a building becomes, even including those of the best construction, the more liable is it to damage during an earthquake, and accordingly it is advisable in construction to make use of such feasible principles as will reduce to a minimum the liabilitiy for earthquake damage and also mortality during the life of the building.

Building conditions in Northern India are different from those in other countries. Here we have three principal types of houses and other structures. The village hut is usually constructed with mud walls and thatched or tiled roof, some are of bamboo-wattle walls with a thin plaster of mud; these are known as *kutcha* buildings. Rather more expensive houses, the *kutcha-pucca* type, are built of brick (usually of poor quality and often even only sun-dried) with mud mortar. The *pucca* type includes well built structures of brick, masonry, etc., similar to structures in most countries. Other types of so-called *pucca* buildings have brick and good mortar in the arches over doors and windows, but the walls are of brick and mud-mortar. In others the walls are faced with brick and mortar but the inside is of brick and mud-mortar. Both types are very common and invite disaster.

KUTCHA BUILDINGS.

The greater part of the population of Bihar cannot afford more expensive types of houses. The mud or mud and wattle hut always will be the villager's main form of residence; it is easily damaged during an earthquake, but as it is equally liable to damage during any rainy season its weaknesses need have little consideration here. It is possible that some slight improvements may be made in such buildings to at least reduce mortality should they collapse during an earthquake. They should never have heavy roofs. Professor Nasu suggests that the walls of mud huts should be thick at the base and thin at the top, the inner and outer surfaces having a parabolic cross-section.

Kutcha-pucca buildings.

It is apparent that *kutcha-pucca* houses must, for many years, form a considerable proportion of the buildings in this area. But some effort should be made to minimise the damage to which they must be subjected during any severe earthquake. No *kutcha-pucca* building of more than one storey should be erected north of the Ganges. All ornamental work such as in cornices, balustrades, etc., should be discarded and the roof kept as light as possible. The walls should not be less than a certain prescribed thickness. Improvements in the type of brick and mortar should be introduced within economic limits.

The use of timber frames in certain types of *kutcha-pucca* and *kutcha* buildings should be encouraged. These frames, formed of sole plate and vertical timbers, should be well tied by diagonal timbers and the roof firmly attached. A number of very old houses built in this way in Chapra survived the shock remarkably well.

For buildings constructed almost entirely of timber, some observations made by Mr. E. R. Gee subsequent to the Dhubri earthquake of the 3rd July 1933, are apposite (1934, pp. 8, 9, 88). The framework of the split bamboo buildings there are sometimes fixed to posts which are either set into a masonry plinth or driven into the ground; in other cases the framework simply rests untied on the masonry plinth. In the former type the fixed posts were often sheared at the base and the building considerably damaged. In the latter type the building was practically undamaged as there was nothing to hinder the structure from moving as a whole, independently of the plinth, and with its own natural period of oscillation.

Pucca buildings.

It is likely that the greatest improvements can be made amongst the larger *pucca* buildings, particularly those used for official pur-

Influence of type of ground.—A general experience is that earthquake shocks are more severely felt on soft alluvial ground than on harder ground. Consequently, given buildings not specifically designed to withstand earthquake shocks, the damage is greater in alluvial tracts than elsewhere. This was, on the whole, our

experience in the case of the Bihar earthquake, although the extremely poor construction has permitted their general collapse even on hills, as at Udaipur Garhi. In the great Napier earthquake of New Zealand in 1931, the houses on The Bluff were scarcely affected, whereas almost total damage was general in the business quarter and other parts of the town which are on the alluvial flats below. Freeman (1932, p. 366) mentions that in the San Francisco earthquake of 1906 the percentage of damage to buildings of a non-rigid type was five to ten times as great on soft ground as on outcrops of older and more consolidated rocks.

When, however, as in many of the buildings put up in Tokyo before 1923, special provision is made to construct rigid buildings with adequate foundations, the damage to such buildings may be less on alluvial ground than on rock. Professor Suyehiro has shown that, by reason of its inertia, the movement of a rigid building on a massive foundation block may be much smaller than that of the sand or mud upon which the foundation rests. Soft yielding sand or mud tends to act as a cushion to the shock, and surges to and fro beneath the foundation, without imparting to it vibrations of large amplitude. According to observations made in Tokyo and Yokohama the period of earthquake motion at certain places has a definite fixed value, especially in earthquakes of short period vibration less than one second. The uppermost soil layer acts as an oscillatory body with its own period of vibration under the effect of earthquake waves of similar period. The natural period of the ground around Tokyo varies from 0·7 secs. for alluvium to 0·3 secs. for more compact rocks. The ordinary Japanese wooden two storey house has a natural period of 0·3—0·7 secs., while for low brick buildings it is 0·1—0·4 secs. Hence in the 1923 earthquake, wooden houses were more damaged in soft alluvium, and brick houses on more compact ground (Nasu, 1935, p. 3).

Foundations.—Foundations must receive first consideration in building construction. The high cost precludes the use of the more earthquake proof types of foundations in residences and such smaller buildings. But even so there is room for much improvement over the older type of foundation, and it should be insisted upon that in buildings north of the Ganges foundations must be strongly tied together, thus making the structure vibrate as a single unit and preventing also any tendency to spread during the shock. The necessity for reducing, as far as possible, the

pressure per square foot on the foundations is obvious. Owing to the weight of the overlying structure, it is doubtful whether the type of ingenious foundation in which the wall foundations rest freely on a shingle bed would be more efficient than the above well-tied type of foundations.

For heavy buildings the foundations should receive particular attention. The amplitude of vibration in soft ground is great, and in heavy buildings, especially, it is necessary to reduce its effect. In the slump belt and epicentral tract of North Bihar the massive reinforced concrete foundations of some of the sugar mills have been tilted and even badly cracked. So far as could be seen the materials employed were of high quality. It may be doubted if even the most ideal foundation, placed on soft alluvium containing water-logged sands in the epicentral region of a severe earthquake, could escape damage entirely, in some cases by tilting. But this is no argument for dispensing with good foundations for important buildings, and without such foundations the buildings would suffer much greater damage and the mortality would be higher. This question of mortality is only too often overlooked in discussing the comparative costs of improved designs. No design and no legislation can be made to apply to the highest zones of damage in alluvial country. The general principles concerning construction in seismic regions have to apply to the type of damage to which the greater part of these regions are likely to be subjected, not to those smaller areas where a combination of factors results in abnormal severity.

A normal well-tied foundation should serve for single storey buildings of no great height, even where the building covers a considerable area. High buildings, or those of more than one storey, should be avoided north of the Ganges, but if necessary, and, particularly where they are likely to contain a large number of people at any time, there should be some insistence that the structures must rest on some suitably designed form of solid re-inforced concrete foundation, forming a platform below the whole building.

General design.—Buildings should be of simple design, the parts so well-tied and the whole structure so rigid that it would react as one unit to earthquake waves. The several parts of irregular buildings do not synchronise during a shock, and severe stresses are set up between the individual units. These remarks apply

especially to high structures, *e.g.*, a church steeple erected on a tower is frequently destroyed from the base of the steeple; the tower and steeple each have a different vibration period and, with opposing directions of movement, the acceleration can be doubled.

Buildings should be kept as low as is conveniently possible, compared with their lateral dimensions. The object should be to keep the amplitude of vibration as low as possible at the highest part of the structure, and so reduce acceleration for any particular period of vibration. In badly constructed buildings the motion increases with the height, but in well-designed and well-built structures the motion is the same from top to ground level.

In this report we have mentioned that the maximum acceleration was about 10 feet per sec. per sec. Notwithstanding that the acceleration during earthquakes in other parts of the world frequently approaches this figure, legislation in Japan and New Zealand stipulates that designs must be suitable for an acceleration of 3·2 feet per sec. per sec. *i.e.*, one-tenth g; in other words, the total horizontal force at any horizontal plane must not be greater than one-tenth the total weight of the structure above the plane. For such structure as columns and bridge piers we would suggest allowing for the higher figure wherever possible.

Buildings of irregular shapes, with wings, protruding verandahs, porches, etc., have invariably suffered. The same applies to buildings to which additions have been made by the abutting of new walls directly, on earlier ones, without dovetailing. The whole building should form one unit. Verandahs and porches should not consist of a series of independent pillars with a roof resting on top, but should be integral parts of the building. If it is impossible to avoid having adjacent structures of different heights and different periods of oscillation, they should be separated beyond the range of collision, and connected by lighter more fragile structures, in which the damage may be safely concentrated.

Excrescences such as towers, turrets, pinnacles, etc., are dangerous both to human beings and to buildings, and should be avoided. Flimsy parapets, balustrades and similar structures have caused death to many.

Windows are a source of weakness to buildings and a more careful and better spacing should be attempted. Windows should be kept away from outer corners of buildings as far as possible. Wide window areas should be compensated by stronger intervening walls.

Roofs.—It has been found that heavy roofs were frequently the cause of serious damage to buildings. During big vibrations the inertia of such roofs breaks up the walls on which they rest. Flat roofs, therefore, should be made as light as possible, and the junction of wall and roof reinforced in some way. Roofs made of reinforced brickwork are lighter, stronger and more graceful than the old type of clumsy and heavy roofs on beams and rafters. The use of flat tiles instead of bricks, where beams and rafters are used, is advisable for flat roofs. Light tile roofs appear to have caused the least damage where the tiles were securely fastened.

Sharp gable ends, so characteristic of churches, should be avoided. During an earthquake they sway considerably and, aided by the thrust of the roof, collapse easily. Hip roofs are preferable to gables.

Arches.—We do not recommend the use of arches in doors, windows and verandahs; during a tremor they are the weakest part of any structure and the first to go. Jack-arches supporting roofs sometimes escape, but are as often cracked along their centres. If use is made of jack-arches, it is advisable to employ tie-rods to hold together the different spans. Bricks in these arches should be staggered and not set in a linear arrangement.

Solid reinforced lintels over doors and windows are preferable. Wherever possible, lintels on each floor should be of the same height and should be carried around the walls as a single band.

Chimneys.—Tall chimneys in factories should not be of brick-Steel or reinforced-concrete chimneys can pass safely through severe earthquake shocks.

Quality of materials.—Perhaps the best advice we can give is that close attention should be paid to the quality of building materials, particularly to mortar. Unfortunately the standard of bricks and mortar used even in public buildings in India is often not as high as it might be. The example of some of the newer railway buildings is well worth following.

In the case of concrete, the panelling should be constructed at the same time as the framework in order to ensure good bonding. Sugar mills should be of steel framework, preferably covered with corrugated iron or other light material. We would suggest that houses erected along the Motihari-Sitamarhi-Madhubani-Purnea belt should be built of steel or timber framework; structures of this type, carefully designed and conscientiously erected, can be as permanent and cool as masonry.

In conclusion it may be pointed out that our remarks in this section apply mainly to the area north of the Ganges and to the vicinity of Monghyr. Otherwise we see no necessity for any drastic changes in building design to the south, although an improvement in materials is desirable.

Roads.

A minimum standard width for bazar streets should be insisted upon wherever possible. This will depend upon the height of buildings erected. The reservation of open park areas within crowded bazaars is as desirable for health reasons as for earthquake escape purposes.

No advice can be offered about road construction but we would remark that the occasional practice of digging deep ditches alongside them is frequently the cause of subsidence of the roads. Ditches preferably should be shallow.

Bridges.

During a severe earthquake in alluvial country, river banks tend to close in and their bottoms to rise up, as a consequence of the general tendency towards the suppression of surface features. No type of structures can withstand such movements, where it is severe, without some damage.

Brick arched culverts and bridges have been damaged most severely and this type should not be built north of the river.

For road bridges screw-piles have proved the most suitable. Piles tend to move up or down during the shock, and movement of the bank tends to bend the piles over. Movement along the stream bed may also displace the piles. After the Bihar earthquake, although pile bridges were acutely distorted they were in almost every case negotiable by traffic. Although easily damaged they can be readily dismantled, straightened and rebuilt.

Frequently it is of course necessary to construct bridges of steel girders resting on masonry piers. The weak points in this type are the piers and abutments. Nothing can prevent their tilting or displacement in a severe shock, but piers should be designed if possible to withstand an acceleration of 10 feet per sec. per sec. from any direction, that is, their width at the base should be one-third of the height of the pier. Girders should also be designed to withstand such an acceleration.

Conclusion.

We have advocated the control of building construction in Northern India by some form of building code. It is not within the sphere of the geologist to discuss the engineering details of such a code, but in the foregoing we have outlined several of the more prominent features of buildings which might be avoided in order to design earthquake-proof structures, and we have drawn attention to them also in order to emphasise the fact that much can be done without the outlay of any considerable expenditure over that usual in building construction in India.

The compilation of such a code should not be a difficult matter. We already have the codes of several other countries to use as a basis. Conditions of building construction in India are, of course, somewhat different from elsewhere; indeed, the *kutcha* and *kutcha-pucca* buildings are unique to India, but it would be necessary merely to extend these other codes to embrace these typical Indian structures. It would be a simple matter for a representative committee consisting of engineers, an architect and perhaps a geologist to draw up a general code.

It is often said that, in a country such as India, the enforcement of a building code would be impossible and might also impose hardship on certain classes of people. So far as private buildings are concerned local municipal authorities could have the necessary control in larger towns, and in villages with their simple houses the local thanas could exercise the necessary elementary supervision required. No such control would be necessary in either P. W. D. or railway buildings, but the code would provide a valuable basis of design for the engineer and architect.

It has also been remarked that as one hundred years have elapsed since the last disaster in this same region, such an interval between earthquakes does not warrant any special legislative measures. If the Bihar disaster had been at night with the deaths running into hundreds of thousands, as they might well have been, it is doubtful whether such an excuse might have been advanced. The next shock may be at night, and, without such legislation, the mortality may quite easily attain appalling figures. Even if such long quiescent periods are worth considering in this matter, we cannot be sure that such lengthy intervals as one hundred years will be experienced in the future. We can only advocate, for the sake of posterity, that within the whole of this seismic

belt of Northern India, all that we can do for reducing mortality and damage in future earthquakes should be done. Leprosy is not a common disease, but the medical profession has done its utmost to eradicate it for the sake of humanity. Great earthquakes are not a daily disease of any part of the earth's crust, but it should be our duty to do all that we can to reduce its effects. Unless this matter is looked upon in a broad way, posterity may yet look back upon our short-sightedness with regret.

In the Quetta area an excellent building code has recently been drawn up, and reconstruction has been rigidly enforced in terms of that code. Such enforcement is, perhaps, easier in such a military area, but at least Quetta provides an example of the practicability of a building code and of its usefulness. It is, perhaps, not too much to hope that the rest of Northern India will some day follow Quetta's lead.

This brings us to future research in India on earthquakes, and the desirability of creating a small Government department whose whole time would be devoted to the study of this subject. The study is too specialised to be regarded as requiring merely the occasional attention of two such departments as the Meteorological Department and the Geological Survey. The whole study could be more thoroughly and authoritatively studied by whole-time specialists. There are two lines of investigation awaiting such a department :—(*a*) the prediction of future earthquakes as to time and place and (*b*) the means of minimising the effects of these earthquakes. Even if we were ever successful in the study of the former investigation, the latter line of enquiry would always be the more important. We have already emphasised the importance of a building code in this matter, but the special Seismological Department which we have suggested would be responsible for obtaining information of acceleration, etc., of earth waves in future earthquakes to aid in improvement of structural designs.

There are not to-day sufficient delicate seismographs to record the normal tremors, but we need particularly a large number of a type of more rugged and less delicate instrument to record the severest earthquakes, and placed at specially selected stations throughout Northern India. Until this is done we cannot advance further in our investigation of these great disasters in India; we have gone as far as it is possible to go with the means at our disposal.

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PART II.—DETAILED ACCOUNT OF THE EARTHQUAKE EFFECTS.

SECTION A.—EYE-WITNESSES' ACCOUNTS.

CHAPTER XI.

INTRODUCTION.

(J. A. DUNN.)

Some explanation is necessary of the reason for the lengthy description of the earthquake effects which is provided in Part II. It is becoming apparent from the study of successive earthquakes of recent years in north-eastern India that, even within the broad belt liable to severe damage shown on Plate 5, certain places are consistently liable to experience a severe shock, whilst other adjacent localities may escape relatively lightly. Severity of damage is not entirely a function of distance from an epicentre but is seemingly dependent on local surface and crustal peculiarities. We may not be able to appreciate entirely the sub-surface features which govern shock intensity during any earthquake, but we should, if sufficient evidence is accumulated, be able eventually to determine those places which suffer consistent severe damage and those which escape lightly. Only detailed experience of a large number of shocks can ultimately demonstrate the areas of comparatively great and less damage. During the course of our survey of this earthquake we tried to obtain some idea of such intensity distribution in the past, but, except for a few principal towns, the information is sadly deficient. It is our object to supply this information at least for this earthquake, so that for future shocks a more detailed comparison can be made from place to place.

We have commenced this description by quoting from the reports of eye-witnesses who were, at the time, out in the country, away from the larger towns in the epicentral tract. These reports are of interest in that they give such a fine picture of the shock and the unusual 'atmosphere' which naturally followed the catastrophe.

Next follows brief accounts of some road and railway traverses made by the authors in the central region, connecting up the damage between the several towns. Chapters XIV to XXIII describe the damage in the principal towns and larger villages of isoseismals

X to VI in turn, from the notes of the authors. In describing the damage within isoseismals X and IX the effect on certain of the principal buildings in each town is noted, but for isoseismals VIII and lower, the description of the damage in each town is generalised. The descriptions for the lower isoseismals given in Chapters XXIV to XXXI are from reports submitted to the Geological Survey in reply to the questionnaires. In each isoseismal the localities are arranged, as far as possible, from west to east. The reports which have been abstracted here form a comparatively small selection from the large number of those received, and are confined to the more important centres.

The description of the earthquake effects in Nepal has been grouped into a single final chapter as this is a distinct region which would be difficult to include within the sequence of the account for Bihar.

CHAPTER XII.

SOME REPORTS BY EYE-WITNESSES.

The first report selected is that by Mr. C. H. Gordon, General Manager of Sursand Raj, who was driving within the central part of the epicentral tract. His account gives a fine picture of the fountains of water which dotted the country-side and the state of the country in general. Mr. Mansfield, Collector of Bhagalpur, was on tour near the Balan river at a point on the easterly extension of the epicentral tract; his tour diary is remarkable for the impression which it gives of the unusual 'atmosphere' created by the conditions following the earthquake. The final report by Sir J. Williamson describes the difficulties with which the railways had to contend.

Mr. C. H. Gordon's account of the Earthquake.

I had lunched at Belsand Factory some thirty miles north of Muzaffarpur, leaving at about 1-40 p. m. by motor for my own place thirty miles to the east, though the first five miles or so of the road lay north. I had gone about seven miles. Going east now, a little after 2 o'clock I should say, my car suddenly began to rock in a most dangerous fashion, the motion appeared to be from the right back wheel to the front left wheel, or from a south westerly direction. Owing to the sound of the engine I noticed no noise, but was told such was heard from the west, a deep terrifying rumble. As the rocking ceased, mud huts in the village, on either side of the road, began to fall. To my right a lone dried palm trunk without a top was vigorously shaken, as an irate man might shake his stick, then water spouts, hundreds of them throwing up water and sand were to be observed on the whole face of the country, the sand forming miniature volcanoes, whilst the water spouted out of the craters; some of the spouts were quite six feet high.

In a few minutes, on both sides of the road as far as the eye could see, was vast expanse of sand and water, water and sand. The road spouted water, and wide openings were to be seen across it ahead of me, then under me, and my car sank, while the water and sand bubbled, and spat, and sucked, till my axles were covered. "Abandon ship" was quickly obeyed, and my man and I stepped into knee deep hot water and sand and made for shore. It was a particularly cold afternoon, and to step into water of such temperature was surprising.

It was distressing to see the villagers, running some east some west, others to, others from their fallen homes, wailing and beating their chests.

In less than half an hour I should say, the water spouts ceased to play, though water oozed out of the land and trickled from the mouth of the lesser sand heaps.

The Raja of Parsowni living two miles away, very kindly sent a man to accompany me to his place. Persuading some passers-by to take some of the luggage I tripped, and skidded, and waded to Parsowni, to find that the Raja Sahib's house was flat with the ground.

Being unable to get coolies to go further, and this was but natural considering the circumstances, I waited with the Raja for some time. His camp being alongside the main road, we heard from passers-by who had run in from long distances that the same conditions existed in the direction from whence they had come. Refugees from Riga, nine miles to the north, told the sad tale of the collapse of the Riga Mill and of many lives lost, but the latter information I am glad to say was found to be greatly exaggerated. These men also reported that the railway line had been badly damaged.

It was now becoming dark, and about 5-30 p. m. I was able to start to walk to Belsand. The road I had but a few hours before driven over did not exist, only sand heaps and flowing water, and pit-falls. It was a perilous journey, no one could have believed that in a few minutes so great a change could have taken place.

I plodded three miles when my host's car met me, it could not have possibly gone further. On arrival I found Mr. and Mrs. Dobson encamped under a tree, their lovely bungalow having fallen in. A roaring camp fire and tinned and bottled provisions were a consolation.

In the morning, on visiting the bungalow, it was a sad sight that one beheld. The roof of this old Dutch building had sat down flat, the walls and pillars, some lying down, some reclining, suggesting weariness after two hundred years of standing. The lawns that had been for years the admiration of many, were now mostly sand dunes, while ugly gashes some three feet wide at short distances disfigured its once beautiful face.

We were marooned, and it was impossible to get or give news. The Post and Telegraph Offices looked like mushrooms that had been trodden upon, there were no roads, and no men were available to go anywhere. On the morning of the 18th, I was able to get a *palki* and twenty-four carriers, and I ventured out to go thirty miles to my home. *En route* I dug out my car with the help of forty coolies and it took nearly two hours ; bridges were down on both sides of the car, so it had to be left in the care of an Indian whose house was on the road-side. It was fifteen days before I could reclaim it.

As I proceeded, sometimes being carried, sometimes walking where conditions made it hard or difficult for the carriers, the scene was just as it was where I had been caught in the earthquake ; it proves that what I had witnessed at the time must have taken place all over the country.

While fording two hill streams that come down through Nepal, they were in flood, high flood, and the water not merely cold but iced, indeed the fall in the temperature was noticeable as one approached, this surely pointed to happenings in the mountains and snow ranges.

I arrived at Sitamarhi at about 1 o'clock, to find it lying in the streets and by-lanes just a mound of bricks ; up to that time, two hundred dead and dying had been unearthed or unbricked, and more were being taken out. Had the calamity occurred at 2 a. m. instead of 2 p. m. one shudders to think of the consequences, particularly as it was winter time when folk are closeted within their houses.

The hospital had fallen killing every patient, except one who had a fracture of the skull and both legs broken. The jail walls had fallen and every prisoner had escaped. The Government Courts and Magistrate's bungalow were down also. In my thirty mile trek, five bridges had collapsed and numerous culverts, and there were cracks across the road of great width.

Jarrived home at 8 p. m. having been thirteen hours on the road, to be informed that the bungalow had been laid low, my servants and furniture, etc., on the lawn. As there was no bed for me I slept in the *palki* after having dined on fresh air and

In the morning it was a sad sight, the bungalow had sunk down on one side, with gaping cracks running right through the rooms and walls looking as though they might come down during any one of the tremors that were being felt, as indeed they did.

I was not alone in my compound, for I found scores of refugees from our little town or bazar, the buildings of which had fallen about their ears. They were encamped in shelters of bamboo, and chadars, and old bags, with goats and cows as companions. I was besieged with questions, " Will it happen again ", " What are we to do ", the sorrow and fright expressed on their faces was depressing, but one had to give them heart and appear collected. For twelve days all communication with the outer world was impossible. No roads, posts or telegraphs, and railways but twists and hair-pin bends.

Stories of the experiences of some are too pathetic to mention, though on the other hand one man who fell into a crack and was disappearing, was suddenly shot up with a volume of water that belched out of the crack, describes one of many lucky escapes.

Many of the wells in the villages have been entirely filled with sand, and of the large tanks, some are sand areas, and in others the depth was considerably shallowed by sand deposit.

Tour Diary of Mr. Mansfield, I.C.S., Collector of Bhagalpur, January 15th—January 20th.

15th January 1934.—Walked to Nauhatta, and thence by foot and elephant to Bakania and out to Dharamgachhi (in Darbhanga) for the Tiljuga enquiry; the Collector of Darbhanga and the Superintending Engineer were both there. Arrived about 12, after crossing the Tiljuga on elephants, in the ' bottle neck ' at a point just south of the temple, which formed a conspicuous land-mark for miles. The space between the embankments is not, as I pictured it, an open space, but full of dense grass and scrub jungle, full of nilgai and pig. After lunch the three of us, with my wife and Mrs. Hall, and the Banaili Engineer, set off on elephants to see the country above the bottle neck, and the Balan embankments. We crossed the westernmost embankment about half a mile above Dharamgachhi and crossed the Balan river, which was up to the elephants' bellies. When we had gone 100 yards into the jungle, the leading elephant stopped with a jerk, and turned round, and so did the others, and appeared to be in great fear. As the mahout said afterwards: " the thought of charging away in terror had come into their hearts ", for as they stood we heard a rumbling sound, like a storm in the distance rushing towards us; eventually one elephant was made to kneel, and one of us got off and could feel the earth shaking, and we then realised there was an earthquake. We jumped off one by one, as soon as the elephants could be got to kneel, which was not done without difficulty, the elephants being bunched together on a narrow path. There we were crowded together, with the elephants almost on top of us, with the thought of stampeding still in their hearts; but fortunately, they and the mahouts were

stout fellows, and they did not bolt. Then we heard a shouting behind us, and people came running to us, who had followed us through the river, shouting: "The water is coming, the water is coming" and charging on towards a village a little way ahead. They said the water had suddenly welled up in the river, and then sunk away, as if the bottom of the river had opened and one man said he had come through almost dry shod! Certainly his feet were covered with mud, but his legs were dry. We then decided it was time to get away from the river bed and on to some higher ground near the village, so started to move on to the village. I was still sceptical of the reports about the rising of the river, but after we had gone 200 yards or so, we saw water bubbling up through the earth in dry fields in front of us—and as we searched for a way to get round it, water bubbled up in other fields as well, until at last it seemed to be all round us, and the only way was to go through it—only angle deep at the time, but one never knew whether one's foothold was going to turn out to be a quicksand, or even a chasm—for the water was all charged with sand and earth, and was black in colour, while, over everything there was a sulphurous smell. To add to all the excitement we had to plunge through clumps of bamboos, and all the time felt we wanted to get on and out of the bed of the two rivers between the two embankments. Presently we came in sight of the village, and there we saw water bursting out over the top of the village well, which was itself raised above the ground. By this time we had got on to a small embankment, but when one of us tried to go along it, it could be seen to shake and quiver under him, and we decided not to try that way. The question then was which way to go, and after some discussion, it was decided to go through the village, and up the Balan to a place where there was a ferry, and so back to camp, a four or five mile walk. We walked through one or two villages, where several houses were down, and where the water had bubbled out of the earth and through the streets and over the fields, depositing a quantity of black sand on the way; but the water was now subsiding. Before we reached the ferry we met a man who had come from across the river, and he said that the ferry boat was sunk, and he had crossed at another place by a temporary bridge, which was a foot under water. We eventually reached this bridge, and by the help of the villagers and hanging on to each other, managed to get across safely, though it was rather trying to go along a few narrow bamboos, which one could not see under the black water. From there we had a two or three mile walk back to camp, and the question was should we find the camp standing. Some said it had all fallen down and was flooded. When we got to it we found it *was* flooded, one tent down altogether, and another one with a great seam in the ground down the middle of it, through which water had spouted several feet high and formed a flood about a foot deep, whose marks were still on the tent walls. Fortunately Freston had an extra supply of bedding (our own carts had been caught by the earthquake when two cart-loads had crossed the river, and one was still on the way across, and they had all gone back to Bakania) and so with Freston's help we spent the night warm enough, in three small tents pitched on a bit of dry land, while the servants occupied tents on another patch. We were fairly cheerful, as we thought it was all over, and that it was a local affair, due to the thinness of the earth's crust in this purely alluvial plain.

But the night was disturbed by the elephants tethered near the camp, which had got back to camp by wading through the river, and had their evening meal off branches of the neighbouring trees, and by further distant rumblings of the

earth—which some of us professed to have slept through. Next morning news began to filter in saying that there was a lot of damage in the neighbouring villages immediately to the west, and not quite so much damage to the east, though we could see for ourselves that the temple which had formed such a conspicuous landmark in the morning, had fallen.

As soon as we could get transport coolies we set off, three of the party to the west towards Darbhanga with two elephants, and myself and my wife to the east with two elephants. We crossed the Tiljuga by a boat, and presently came up with our luggage, which had been left behind the previous day. There we sorted out our things, and putting our most necessary baggage and some cold food with a small tent on one of the elephants, and taking four or five coolies, we set off on the other elephant to Nauhatta, our other baggage following behind on carts. The most trying part of the journey on the elephants was in crossing several depressions and patches of water, which were deeper than they were when we passed them the day before, where the elephants went very gingerly, in case any crack in the ground should be there, hidden by the water. Every now and then we felt more shocks, one at 11 and another at 12; and we passed great cracks in the ground, which seemed to get worse and worse as we approached Nauhatta. Water was still standing in many of the fields, and it appeared that the surface of the earth was a series of shallow waves, about a mile or so from crest to crest, the tops of the waves being more or less dry, though split in places, and the depressions being filled with larger cracks, and covered with shallow water. Near Nauhatta we met Hood (assistant manager of the Banaili Estate) who was coming out to see what had happened to us. He told us the bungalow at Nauhatta was cracked, all the brick houses down, huge cracks in the ground, the temple tilted and crooked, and at least one person killed by the fall of a wall. We preferred walking to going on an elephant, as tremors were still going on, and on those occasions you feel less safe on the back of an elephant than you do on the ground; but sometimes we had to ride, to save our legs for a long journey, and to get dryshod through the patches of water. By now we knew that the railway was out of order, and the telegraph wires down, and began to fear that the earthquake was much bigger than we at first thought; in fact a peon soon arrived bringing a message, which had somehow come by wire from Madhipura, saying all the public buildings there were damaged—20 or 30 miles away from us. We reached Nauhatta and explored the village, and sure enough there were cracks and holes through which the water had gushed up big enough to hide an elephant, or almost two. Houses down in all directions, and in one place a wide slab of earth had sunk a whole foot below the rest. Here, as in other villages, the wells had become filled with mud, and we had to warn the villagers to be as careful as they could, and use tank water for all purposes except drinking, and reserve the well water for drinking. At Nauhatta we had some food, about 2 p. m., and then being disappointed in our hope that a car could reach us there from Supaul (10 miles on), we decided to push on on borrowed bicycles, taking our necessaries with us on a new relief of coolies—for the elephants were tired, and at any rate we were tired of going on elephants. At last we collected coolies and bicycles and set off, and when about five miles from Supaul were relieved to see the Subdivisional Officer coming out in his car to fetch us. We went back with him along the road as far as we could, a mile or so, and waited a short time until the coolies turned up; then we loaded the luggage in the car and

returned to Supaul. At Sukhpur the damage seemed to be as much as in Nauhatta; but near Supaul there was not much water about; nor was there much in Supaul itself; but many houses were down, and there had been one death. People were preparing to spend the night in the open, though there had been no tremors since about noon.

The bungalow at Supaul was cracked and unsafe, so we had a small tent pitched and presently another tent appeared; and as the Commissioner's servants were there we had a hot dinner instead of a cold as we had expected, and the first bath for two days. We spent a less uneasy night than the last.

Next day all seemed cleared off; I walked round the public buildings, all of which are cracked and many of them quite unsafe—the court, the registry office, the school, the jail—all. In the jail I had to give orders that the prisoners should not be locked up in the wards at night; for in some buildings the doors were shut, were jammed and could not open, and we could not run the risk of prisoners being inside a locked and jammed building. At the hospital patients were in the open, and a tent was therefore put up to accommodate them. By now rumours began to filter through of disasters at Darbhanga and Muzaffarpur and Monghyr. At Monghyr, the rumour came from a man, who was said to have come from there by a bicycle, that the whole town was flat, and 7,000 or 8,000 people were dead. Even allowing for exaggeration, it was evident that there was an appalling calamity. At the station we heard that the Sonepur bridge was damaged—opposite Patna—so God knows what can have happened at Patna. Even now—the evening of the 17th—we do not know. These reports, with occasional tremors still going on, make us feel depressed, to say the least. After lunch, and after giving some instructions to the Subdivisional Officer we went out a few miles to the east on bicycles. Mine was too small, and after a bit I preferred to walk. For a few miles east of Supaul there are few cracks in the ground, but *pukka* houses are damaged. The sugar factory is badly damaged and the verandah has come completely away from the Campbell's bungalow. Further east the cracks in the ground and the water-spouts increase again. After getting back to Supaul I held a meeting of the local people and the salt and oil dealers, who agreed to a system of control of prices by the Subdivisional Officer. The prices of oil and salt were fixed, stocks were to be reported to the Subdivisional Officer, sales to people in the town were not to exceed ½ seer salt and one bottle oil, and sales to people outside the town could be made in larger quantities only on the order of the Subdivisional Officer, who would only give that order when the applicant agreed to sell in turn at a fixed price. We went to see the patients in the hospital, who are now sheltered in a large tent. The 2nd officer returned from near Pratapganj, and reported similar conditions up there. Spent the evening making arrangements to depart early next day, the route being through country of which the condition was not known. Received definite news of Bhagalpur for the first time to-night; *viz.* a wire to some private person saying there were "great troubles" there, and a constable, who had returned from there *via* Mansi, and reported 100 deaths. Had I known the earthquake had affected Bhagalpur badly I would have returned earlier, and if I had known trains were running from Mansi, I would have gone that way. But having arranged transport to Madhipura and wired to the Subdivisional Officer that I was coming, I decided not to alter my plans, especially as I was anxious to see the state of affairs at Madhipura.

18th January 1934.—Up at 6, but it took 2 hours to collect the necessary coolies and to get the loads sorted. Left at 8 in the Subdivisional Officer's car, which took us to Dhimra, whence we had to walk 3 miles to the level crossing at Jagatpur (the coolies having come 4 miles along the railway). Thence walked to Laukaha, where fortunately the villagers were helpful. They soon provided a couple of fast bullock carts, and the coolies cheerfully undertook to go as far as I required, provided they were fed, and food was fortunately available at a bazaar a couple of miles on. After halting an hour we went on, across country which is affected, but not so badly affected as Nauhatta. Near Jogbani met a Head Constable and a peon, who had come from Madhipura to meet us (my wire had reached the Subdivisional Officer only about 10 a. m.). Eventually reached the Kosi and got a boat, and arrived at Madhipura at 6 p. m., having done 20 miles by foot, bicycle, cart and boat, besides a few miles in the Subdivisional Officer's car. Everything had gone like clockwork on this journey, which would have been really enjoyable if it had been made for any less tragic reason than it was. Constable Chotey Singh (No. 203) who was deputed to accompany me, did very well and worked cheerfully and I said he would be given a good mark.

Spent the evening walking round the town with the Subdivisional Officer, and talking to the people. All public buildings are badly cracked—much worse than at Supaul—the hospital is quite unsafe and they are unable even to get at the medicine. I instructed the Subdivisional Officer to put up a tent, and get some medicine from surrounding dispensaries, and start the hospital again. Many houses of local people have become irreparably cracked, and I understand there will be no local objection to shifting the headquarters of the Subdivision. The Subdivisional Officer has already taken steps to control prices. The town is in a miserable condition—water everywhere, and the treasury cannot be opened. But there were no casualties in the town, and only 6 in the whole police station. Spent the night in a tent.

19th January 1934.—Up at 4-45 and left at 6-30 a. m. for the Ghat, and then left in two boats by the Kosi. I was informed the journey to Badla Ghat would take 6 hours; allowing for excessive optimism, I thought it would be 8 hours. Actually we never reached Badla, and have now (5 p. m.) changed course to Dhamara; even then we shall not arrive till about 9 p. m., and thence will have to walk 8 miles to Mansi. Progress is dreadfully slow, and my regret is that I did not get any news from Bhagalpur earlier, or realise that it was much worse off than Supaul or Madhipura until the 18th evening. I must get back by to-morrow morning, whatever happens.

Continued on 21st January 1934.—From 6 to 8 p. m. we were progressing painfully along in the dark, on a very cold evening, up a tributary of the Kosi, trying to find the railway. The country looked quite desolate and seemed to have no habitations at all. Lights appeared in the distance, but seemed to be will o' the wisps, and we began almost to wonder if the railway had ever existed. Across the river we saw houses, and we shouted but got no reply. We poled across to examine the inhabitants, and then discovered that the houses were clumps of grass. At last we saw more lights, and these turned out to be real, and then we saw the railway bridge. We questioned the people as to the way, and found a ferryman; when requested to show us the way he said he had not had his meal yet. He was greeted with shouts of "neither have we, and we have rowed all day", and he had no

alternative but to come. We now turned into another stream (downstream this time) and presently ran into a stout barrier across the river, which held us up. Our boat turned sideways on, and our second boat came charging into us, and there was almost a danger of ending our day's journey in the cold water. Eventually we got through the barrier of stout posts, and shortly landed at a village, whence the road runs to Mansi. Presently we were greeted by a European girl, who we found was staying in a Zamindar's cutchery with her mother. They took us in and gave us some hot tea, which we enjoyed at 9 p.m.; and as we had a tiffin box full of food with us we were all right; and as there was a shop our servants and boatmen were all right also. We learnt that there was a train from Mansi at 2 a. m. (8 miles off) and I was relieved to find there was a road to it, as I had visions of going along the railway line, and having to cross the river at Badla Ghat over the railway bridge, which was probably precariously tilted at any angle, with no parapet. We left at 10, myself and my wife, one servant and one chaprasi, carrying one lamp and a torch, and a couple of coats and a blanket, a thermos of tea and a large apple and some chocolate, and accompanied by two men to show us the way and to help us at the ferries over the two rivers. The two men, who were ferry men, turned back after seeing us over the second river, and we went on alone. It was only 4 degrees above freezing point, and we were glad to walk. At 12-30 we heard a tremendous shouting in a village, and the earth was felt to be quaking again; the birds in the trees were disturbed and thousands of crows fluttered out with a tremendous noise. Although we were within 20 miles of Monghyr there was not a crack in the road though many houses were down. As we approached the station we heard a train, and our hearts sank, as we had visions of spending hours on a cold platform. But it was only shunting, and we caught it. We began to hear more news, and our worst fears about Monghyr were confirmed; but Bhagalpur news was better, and we heard there were only 6 deaths. In exchange we were able to give some news to anxious enquirers about Supaul and Madhipura. At about 2 the train started, and the cold was intense. What the poor people living in the open with only thin coverings must have suffered, must have been terrible. But we were so tired we could sleep under any conditions. About dawn we reached the Ganges, and were told the steamer was late and we must wait. But it soon arrived, and was warmer than the train, and we got some tea and a curious tasting bun. We landed and found no car had come to meet us, as we expected; and we had to walk a mile and a half home, carrying our lamp and our rug and our thermos. We reached our house and found tents up and our furniture all out of the damaged house, in tents or scattered about the garden. We have nothing to grumble at and we have suffered no loss at all.

Extracts from a report by Sir J. Williamson.

When the shock occurred, all trains to the east of Gorakhpur automatically stopped running; a number remained stranded for days between stations. Orders were issued to run no trains during the night of the 15th-16th; next day trains on the less seriously damaged portions were got through at restricted speeds. There were several instances of wagons being thrown off the sidings in stations and capsized.

On the 15th one of the principal days of the Magh Mela, accompanied by the Traffic Manager, I had been inspecting the arrangements at Allahabad and Benares. An hour or so after the shock occurred, severe but not alarming at Allahabad, a telegram was received intimating the destruction of two spans of the large Inchcape bridge over the Gogra near Chupra and we immediately started by special train in that direction. On reaching Benares and Aunrihar, as was expected, telegrams intimating very extensive damage elsewhere and that the Turtipar bridge between Bhatni and Mau was impassible, were received. On arrival there at dawn of the 16th inspection showed that the bridge was safe for the passage of trains at slow speed; girders had been displaced longitudinally on their roller bearings, the piers having moved and been displaced as has been found to have happened to nearly all girder bridges on well foundations, and that one well and pier had canted several inches upstream.

At Salimpur station where the Barhaj Bazar and the main lines join, bridge No. 4 (2/12 ft. girders) has been badly shattered but was quickly cribbed up, the line slewed, and trains got through. Except at these three points, the large Inchcape and Turtipar bridges and Bridge No. 4, little major damage has occurred on the Doab lines.

On the 16th accompanied by the Traffic Manager, I went to Tirhut. Owing to the general destruction of telegraph wires, little information except from along the main line could be got; telegrams were badly mutilated and much of the information so gleaned was subsequently found to be garbled. Even now, nearly three weeks later, authentic particulars about the Darbhanga-Bairagnia and Sakri-Jaynagar Sections, are just being obtained.

I inspected down to Khagaria and then to Samastipur and on the 19th managed to trolly through as far as Sakri and on the 20th from Muzaffarpur towards Motihari. From what was seen, a fairly accurate idea of the earthquake action could be gathered.

Of the 2,100 miles comprising the Bengal and North-Western and Tirhut System, it may be said that on 900 miles traversing North Bihar and the eastern United Provinces hardly a mile of track was undisturbed · embankments settled and even disappeared entirely, the rails remaining suspended; elsewhere they were raised or shifted many feet laterally. The permanent way even where least distorted may be likened to a construction line on a high new bank which has passed through a heavy monsoon without attention. So severe is the distortion in places that a trolly could not be safely taken round the kinks. Not a bridge remains undamaged from minor cracks in arches, wing walls and abutments, displaced piers and girders, to complete destruction. Training works and guide-banks of large bridges have been cracked and shaken. Few buildings remain unscathed; some, such as Haiya Ghat station are entirely shattered, others partially so, and few are without cracks and damage of some nature.

The devotion of the staff to duty despite the severe nerve-wracking experience they had undergone was very marked indeed. Patrolling was immediately started, permanent way gangmen themselves taking the initiative, and very soon trains were got through on sections of the main line found safe to run over.

The Engineering staff very promptly got going, first of all on the more important lines, picking up settlements, straightening and bolstering up damaged bridges with sleeper cribs and packing on piers, adjusting displaced girders, and doing what

was sufficient to get trains through at low speed. The main line was quickly got through to the Bur Birdge near Khagaria where passengers are being transhipped, and from there to Katihar. It will be at least the end of February before traffic can be got over the bridge, one pier of which has sheared in three places; the top portion displaced longitudinally is really supported by the girders. Arrangements are being made to support the girders on staging and to dismantle and rebuild the pier.

Between Hajipur and Muzaffarpur through running became possible on the 24th January; extensive damage has been done between Kurhani and Turki.

The next section to be got through was from Bachhwara to Samastipur with a lengthy diversion round a destroyed bridge near Pusa Road and through running was re-established on the 27th.

On the Mansi-Bhaptiahi Section running between Mansi and Saharsa was opened on 1st February and it is expected to open up to Bhaptiahi towards the end of the month. There are numerous diversions on this section.

The Saharsa-Dauram Madhipura branch is severely damaged and the Tilaway bridge destroyed. A train has been cut off on the Dauram-Madhipura side and when the section has been temporarily repaired, probably by the 7th of February, it will be worked as a shuttle train with one transhipment as used to be done during the rains.

Running between Samastipur and Sakri will be resumed about the 15th of February. Amongst other severe damage on this line, the 100 feet spans of the Bur Gandak bridge near Samastipur and of the Bagmatti bridge, have over-ridden the roller bearings and will have to be jacked up and adjusted. One pier of the Bagmatti bridge—the second from the north abutment carrying the 40 feet spans—has sheared; this river is now dead—the bed silted up years ago—so that the bridge can well be shortened; therefore the two end 40 feet spans are being removed and the embankment carried out to the 3rd pier which will become the abutment. Diversions are being constructed round several other bridges.

The Sakri-Jaynagar branch has been very severely knocked about; at least five diversions with pile bridges will have to be constructed but it is hoped to get trains through as far as Madhubani by about the middle of February.

Between Sakri and Tamuria on the Eastern Branch, running will also be resumed about the middle of February, but further east to Bhaptiahi progress is uncertain as damage is more severe.

On the Khagaria-Hassanpur-Samastipur line, diversions have been constructed at places and traffic was resumed and communications quickly restored with the exception of the Bur Gandak bridge near Rusera Ghat several piers of which have been fractured and girders displaced. Temporary repairs are being effected and it is expected that trains can be crossed over this bridge by the 15th of February which will afford a through route without transhipment from Katihar *via* Khagaria-Samastipur and Muzaffarpur to the main line at Sonepore.

On the Muzaffarpur-Bettiah Section damage is very great; the Dhanauti bridge, 4 spans of 60 ft. girders, between Jiudhara and Motihari, as also many smaller bridges, have been totally destroyed. Diversions are being constructed with a large diversion and pile bridge round the Dhanauti. It is, however, hoped that trains can be run through to Motihari and Bettiah by the end of February which will re-establish rail communication with the Bettiah-Motihari, Bagaha and

Bhikna Thoree lines where no great damage was done and over which train services have been run since shortly after the earthquake.

Communication with Raxaul from Narkatiaganj will be opened on the 7th of February.

The Sagauli-Raxaul line is severely damaged especially in the Sikrana valley, where the girders of several bridges have fallen and it is doubtful if this Section can be re-opened before the monsoon.

The Captainganj-Thawe and the Chupra-Mashrak-Thawe-Savan loops were re-opened section by section with diversions round numerous destroyed bridges. Through running of trains was resumed on the first mentioned section on 17th January and on the latter on 2nd February.

On the 26th January a steamer service for passengers and parcels was commenced over the Gogra for the Inchcape bridge between Manjhi and Bakulha stations and is well patronised.

The two 200 feet girders of the Inchcape bridge which have fallen are much damaged; it is, however, possible to build up one complete span from the undamaged members to be cut from the two and by obtaining another complete span to re-open the bridge before the monsoon. Until the Muzaffarpur-Bettiah route is re-opened communications with north Champaran district is being effected *via* the Gorakhpur-Chhitauni Branch with a boat ferry over the Gandak river between Chhitauni Ghat and Bagaha station. Lines are being laid in across the river bed from these stations on each bank to the main river channel to facilitate transhipment.

Needless to say lines which are being re-opened are at present very primitive; any means available to get trains going at restricted speed have been employed. A great handicap is the waterlogged condition of the country, all water levels being high, which hampers earthwork, etc.

As already mentioned, our large stations in Tirhut, Muzaffarpur, Samastipur, Darbhanga, Sakri, Narkatiaganj have stood up well and escaped severe damage. At Muzaffarpur the old engine-shed collapsed, burying a couple of engines which have now been dug out. At Samastipur the chief damage in the Locomotive Workshop is to the old boiler and blacksmith's shops, and the Saloon Shed; they will have to be re-built. The Workshop chimney was badly shattered and has been dismantled; since the electrification of the shops it has been out of use and need not be re-built. The end walls of the new engine-shed collapsed. The contents of Store buildings were thrown about and some kerosene, castor and linseed oils lost.

The water supply and the electric current at Samastipur and Muzaffarpur were interrupted but resumed within a couple of days; repairs had been effected. The 6″ pumping main from the Bur Gandak at Samastipur was broken in many places and spigots drawn from the sockets. Muzaffarpur piping was also damaged but the deep tube well was not put out of action. Machinery in Samastipur shops does not seem to have been damaged.

At Sonepore the traffic officers' bungalows and staff quarters, especially those on the north side of the station, have been badly knocked about.

Everywhere tales are told by the staff of miraculous escapes of themselves and families staying in Railway quarters. So far as is known at present, only three were killed, a carpenter and a coolie in the collapse of the Engineering Workshop at

Samastipur and one of the Loco. Staff; a few have been seriously injured. Many have, however, lost families and relatives at their own homes.

Additional Assistant Engineers and subordinates and Permanent Way men have been equipped and sent to the stricken area. Until Resident Engineers and Assistant Engineers can devote time to make a detailed survey of the damage and prepare estimates—this is now being taken in hand—it is impossible to give any close figure of the cost of reconstruction. Several years will be required to restore bridges, buildings and track to the normal standard.

SECTION B.—GEOLOGICAL SURVEY OBSERVATIONS IN THE CENTRAL TRACT[1].

(A. M. N. Ghosh.)

CHAPTER XIII.

ROAD AND RAILWAY TRAVERSES.

Hajipur-Muzaffarpur.—Although the railway between these two stations was damaged communication was restored soon after the earthquake. The motor road was not seriously affected. The following observations were made partly from a moving train and partly from a motor car.

Both railway and road between Hajipur and Bhagwanpur (16) did not appear to have been damaged to any great extent. At the village of Sarai, W. N. W.—E. S. E. walls of houses were damaged. The wells in this village were not filled with sand. Several large isolated patches of sand, silt, etc., were noticed east of the railway track here and there between Hajipur and Sarai and more towards the latter station. Thatched huts, as noticed from a running train, appeared to be undamaged. Patches of fine yellowish brown sand and silt were seen on the eastern side of the railway line about a mile south of Goraul. The worst damage was between Goraul and Muzaffarpur. About 16 miles from Muzaffarpur cracks and fissures six inches to 12 inches wide, were mainly parallel to the railway embankment but occasional transverse fissures crossed the line. Mud craterlets, confined to the low lands on both sides, continued abundantly for a couple of miles. The diameter of the vents varied from six inches to over two feet. Kurhani station was not much damaged. The walls, facing the railway lines, of a temple at Turki collapsed. The station building at Turki did not suffer much but cracks developed along the length of the *kutcha* floor of the station platform and ejected fine silt. Along the District Board road abundant sand vents were noticed about seven to eight miles from Muzaffarpur and wells were filled with sand, but the road bridge about nine miles from the town was undamaged. Two miles from Muzaffarpur a pillar fell towards S20°W and its measurements gave an acceleration of 2759 mm. per second per second.

Mr. Chandreswar Prosad Narayain Singh, M.L.C., Chairman of the District Board, Muzaffarpur, was travelling in a railway train which had left Muzaffarpur and was proceeding towards Turki, when the earthquake took place. He was reading a newspaper and suddenly felt a jerk which was followed by a tilting movement and the carriage tossed from side to side. He saw the telegraph poles bend and heard the wires twang. The train stopped and, alighting, he immediately noticed a volume of dust in front of him. Realising that it was an earthquake Mr. Singh looked towards Muzaffarpur and noticed that the sky was almost red, being laden with dust and smoke. The railway lines were buckled and the direction of undulation seemed to be north-south approximately. Water spouts appeared, on the low lands on both sides of the railway lines, to heights of over one foot.

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[1] This section has been written with the help of the field notes of Dr. Dunn, Mr. Auden and the author. The portion relating to N. Bengal and Darjeeling was supplied by Mr. Wadia in the form of a note.

Muzaffarpur-Sitamarhi Road.—This road was built on an embankment as most of the surrounding country consists of low lying swamps and marshes. The road was so severely damaged that through traffic was impossible for some time before the various damaged bridges and culverts could be temporarily repaired. The embankment disappeared in places, the road was brought down to the level of the surrounding country, and became very uneven and in places tilted. Large areas of the surrounding country were covered with water, much of which emerged from sand vents and fissures which dotted the surface. The road was, in places, covered with a thick layer of sand. Banks of rivers closed in, as indicated by the buckled pile bridges. The worst damage was within the first ten miles from Muzaffarpur, where the road was often undulating and cut by fissures. Portions of the road remained unaffected, as between miles 17-18½, and sometimes even arch and steel bridges were intact. The last 10 miles to Sitamarhi were not very bad but a considerable amount of sand was emitted. A detailed account of the condition of this road, which cuts across the most severely damaged tract in Bihar, is appended (mileages refer to distances from Muzaffarpur):

0-7 miles. Fissures parallel to the road were frequent, roadway subsided at many places; sand vents numerous in the surrounding low lands.

7-8 miles. Road embankment sank four to five feet and bottoms of adjacent *jhils* were raised.

8-9 miles. The road near Dharampur village dropped five feet and was two feet under the flood water. The masonry culvert No. 18 collapsed, the arches near the middle gave way and one of the piers sank and was tilted towards the south-west. A girder bridge was buckled up and down and the end pillars sank one to two feet, but the middle ones were undamaged. The buckling was most pronounced near the centre and there was a slight lateral displacement of the piers.

9-10 miles. Slumping considerable. Screw pile bridge was safe, although there were a few cracks in the abutments. Of the ten arches of the masonry culvert No. 23, the three central arches collapsed and the eastern and the western walls were cracked. The bridge sank towards E. 15°S. but there was no lateral shift. Near this bridge lowland was covered by five to six feet of sand.

10-11 miles. Slumping considerable. The screw pile bridge, No. 27, fared badly. The central piers were raised to two to three feet above their original positions the girders being bent upwards. The northern abutments sank and were more damaged than those on the southern side. The alignment of the bridge was unaffected. The masonry culvert No. 28, consisting of five 12 feet spans collapsed. The masonry culvert No. 30, consisting of four 15 feet spans also collapsed.

11-12 miles. The worst part of the road was at mile 12. At Rampur Hari, many mud huts were cracked but only a few collapsed. Several pillars of the verandah of an unfinished *kutcha-pucca* house fell respectively towards N.30°E. S.25°W. and S.30°W. and

gave an acceleration of 2,400 mm. per second per second. Almost all the wells were filled with sand. A screw pile bridge was buckled up and down. From 11½ mile onwards sanding was ruinous and thousands of sand vents were noticed in the low grounds.

12-13 miles. The country on both sides of the road was badly affected by sand vents, and about mile 12½ the road was thrown into undulations.

13-14 miles. Sand vents were numerous and the road undulating. The Khanua screw pile bridge was buckled laterally to the extent of four to five feet in an easterly direction. The central part of the bridge sank two to three feet and an easterly shifting of the bridge was noticed near the northern end. All the pillars were tilted towards the north bank. A pier near the northern end of the bridge sank and fissures ran parallel to the north bank of the river. The next bridge (over an abandoned river bed) to the north was raised. One of the piers of this abandoned bridge lay hidden for years and was exposed by the road sinking about two feet six inches.

14-15 miles. The northern bank of the Bagmati was heavily sanded and cracks ran parallel to the river bank. The road was undulating for some distance and at mile 14½ was levelled with the surrounding land. A screw pile bridge was buckled. Near the 15th milestone, fissures were both parallel and transverse to the road and sand vents were numerous.

15-16 miles. Copious sand was ejected on both sides of the road.

16-17 miles. The Marni river bridge, 270 feet long, was badly buckled up and down and sagged about five feet. Both abutments were tilted; the central pier was upright but other piers were tilted towards either bank. Two masonry bridges just beyond were only slightly damaged. From 16½ mile to the end of the 17th mile there were only occasional patches of sand.

17-18 miles. Sanding was in a few isolated patches. Bedaul village was little affected. Two masonry bridges were slightly damaged.

18-19 miles. Sanding was slight and conditions much improved. The large masonry culvert at mile 18½ was severely damaged.

19-20 miles. Road level sank near the 19th milestone. Further on the road was badly affected and was undulating. East of Dhanespatti, the road and surrounding land was covered by sand and water. The temple at Dhanespatti was undamaged and the masonry culvert near the village remained intact. A few houses in the village fell.

20-21 miles. The road was undulating and much sand and water emitted. The village of Runi was badly affected and surrounded by water. At 20¾ mile the surrounding land was covered with sand.

21-22 miles. North of milestone 21 the road was free from sand and the condition good up to Saidpur village, which is on an elevated

tract of land. The masonry bridge about the end of this mile was little damaged.

22-23 miles. Conditions were good up to 22¼ mile, but north of Morshad the fields were heavily sanded to a depth of one foot six inches.

23-24 miles. The screw pile bridge at the beginning of this mile was intact but the road was undulating for about quarter of a mile. Further on the road improved and sanding was practically absent.

24-25 miles. Near the screw pile bridge the road was undulating and sand was emitted about 100 yards south of the bridge. About 400 yards from the 25th milestone the road began to undulate but at Thumba village conditions improved to a great extent. The girder bridge at about mile 24½ was unaffected.

25-26 miles. Only slight damage to the country side was noticed about 300 yards from the 26th mile.

26-27 miles. At mile 26¼ the fields were dotted with sand vents and covered with sand over 12 inches, especially north and east of Banauli (26½) although the village itself was undamaged. From this village onwards the road was undulating for over quarter of a mile and sand vents filled the fields on both sides with sand and water. Further on conditions improved slightly up to within a furlong from the 27th milestone.

27-28 miles. From the 27th milestone the road was badly damaged. There appeared to be a sudden increase in intensity of the shock as was evident from the collapse of houses at the village of Garha, where sand accumulated to a depth of several feet in houses and over the road. There was a slight improvement beyond this village but about 300 yards from the next milestone (28) conditions became bad once more.

28-29 miles. At the beginning of this mile crops were damaged by sand and road and low lands were intersected by fissures; both sides of the road were water logged. Conditions improved slightly beyond 28½ mile, but near the end of the mile the road was undulating. The village of Premnagar near the 29th mile had considerable sand deposits.

29-30 miles. The village of Subhri at the beginning of this mile was also badly affected and the road undulated for some distance beyond the village. Buildings were damaged near Lagma and the road was affected by fissures and sand vents near the end of this mile, where the sand deposits were six to nine inches thick.

30-31 miles. The road was badly undulating for the first quarter of a mile. Further on some sand was noticed and a few fissures near the end of this mile.

31-32 miles. Along most of this mile the country is highland and was little damaged by fissuring and sanding. A few fissures were aligned parallel to the road.

32-33 miles. Neither the road nor the adjacent crops were much affected.

33-34 miles. The road and *bunds* on both sides were very badly damaged and covered with thick deposits of sand; fissures and sand vents continued for about half a mile from the beginning of this mile. Over the last 600 yards of the road, however, damage was slight.

34-35 miles. The first half mile of the road and the surrounding country escaped damage. Damage in Muniari Kuthi village was slight. The last half mile was badly affected by sand vents and the road was undulating.

35-37 miles. Along the last two miles into Sitamarhi damage by fissures and sand vents was heavy and the road was frequently undulating. Grey sand attained a thickness of two to three feet. Some places were riddled with sand vents and the heights of craterlets varied from six to twelve inches.

Muzaffarpur-Motihari-Bettiah Road.—Mileages refer to distances from Muzaffarpur.

9 mile. At Kasba Kanti several houses were fissured. No sanding took place.

10 mile. Emission of sand became abundant from this mile.

13 mile. Wells were filled with sand and their masonry lining broken.

16 mile. *En echelon* sand vents aligned N.35°E.-S.35°W. were noticed in the fields.

18 mile. Emission of sand was very heavy at the village of Motipur.

21 mile. Lines of sand fissures were striking N.28°E.-S.28°W.

23-31 miles. Very little sanding took place along this stretch and only a few houses were damaged. Railway lines at Maisi were undamaged.

31 mile. At Barachakia the land was not badly affected.

35 mile. Sanding was very heavy along this mile.

36 mile. Many fissures were present.

37 mile. Sanding was bad at Pipra.

41 mile. The road was considerably damaged by fault-fissures. Emission of sand and water was heavy.

44 mile. The road was very badly damaged. Sanding and fissures excessive.

46 mile. The road was better and there was less sand.

6 miles from Motihari.—The road was bad.

9 miles from Motihari.—Extensive floods took place. Wells in village were filled by sand.

Flooded country and sand continued to within about two miles of the Sagauli side of the Lohera turning. Towards Bettiah conditions improved, the intensity diminishing about ten miles from Bettiah.

Bettiah-Gobindganj-Kesariya-Pipra Road.—Emission of sand was more or less bad up to 14 miles from Bettiah. At Lakanipur there were small floods and but for small cracks the houses were unaffected. The 20th and the 21st miles were over swampy country, but no sand vents or fissures were noticed. There were a few cracks in the houses at Gobindganj and the fields were undamaged. Sanding

and fissuring began at Sangrampur and houses were cracked. Conditions were bad at Kesariya, houses had fallen and the land was fissured and sanded. No sanding took place for five miles north of Kesariya. Beyond this village, however, damage was considerable on both the Pipra and Sagauli roads. At Sidhi Bazar the sand fissures were five feet wide. Along the Old Bettiah road, sanding and flooding were prominent up to within ten miles of Bettiah, after which they were less conspicuous though sporadically present.

Sugauli-Raxaul Road.—Collapse of houses and subsidence of land along this road were a general feature, especially one mile north of the Sikrana river, but not actually along the river itself. The screw pile bridge near Ramgarhwa was almost intact. The station buildings at Ramgarhwa were slightly cracked and a well 24 feet deep contained 15 feet of sand. Collapse of houses in the village was slight.

Motihari-Dhaka Road.—Near Motihari this road was badly affected but emission of sand lessened about five miles from Motihari. Beyond Sikrana a little sanding took place becoming worse near Dhaka particularly four miles to the E. S. E. of Dhaka and around Dhaka Thana. Mirpur village, about three miles on the Motihari side of Dhaka, contained many fallen houses.

Muzaffarpur-Darbhanga Road.—This motoring road was impassable for several weeks after the earthquake. Causeways sank and bridges were either destroyed or rendered unsafe and the road was in many places intersected by fissures. For the first 15 miles out of Muzaffarpur, fissures and sand vents were very abundant on both sides of the road. Beyond this the road was practically undamaged by fissures for a distance of about five miles. From mile 25 sand vents and fissures reappeared in profusion, particularly around Simri and towards Darbhanga. The following details were kindly supplied by the District Board Engineer of Muzaffarpur. Mileages refer to distances from Muzaffarpur.

7th mile. A tree fell at the 7th mile towards E.10°S. Road was faulted.

8th mile. Portion of the road about 150 feet long sank three feet and was cut up by fissures striking parallel to the road.

9th mile. About 250 feet of the road at one place sank about five feet. The brick paving sank and was damaged.

10th mile. Near the Gandak river about 180 feet of the road sank some five feet. The road was cut up by eight fissures.

11th mile. The entire portion of the metalled road some 80 feet in length sank bodily about three feet and the road was riddled by innumerable fissures.

12th mile. The wing walls of a masonry culvert were damaged by cracks. Small fissures traversed the metalled road. Sanding was not extensive.

13th and 14th miles. This portion of the road was overrun by fissures. Extensive sand and sand vents, like porridge, over the fields.

15th mile. The arches of the masonry culvert were cracked. Fissures traversed the metalled road. Heavy sanding in the country-side.

16th mile. The Berua timber bridge was badly damaged, the eastern abutment piles sank and the central piles in one row were raised. The side beams were damaged. In several places fissures caused subsidence of the road. The masonry culvert east of the

Berua causeway was damaged, its abutment and wings sank and the arch cracked.

17th mile. The Berua causeway sank at several places. Arches of the masonry bridges Nos. 12 and 13 were cracked. MB. No. 14 was pushed towards the west and its arches cracked.

18th mile. The eastern wings of MB. No. 15 were heavily cracked and its masonry damaged. The arches of the masonry culverts Nos. 16 and 17 were cracked and the wings settled. Four re-inforced slabs of cement concrete of the Jarang causeway were raised and cracked. About two miles of the country was under water but little sanding took place.

19th mile. Several fissures intersected the metalled road.

20th mile. The screw pile bridge was dilated.

21st mile. Several fissures crossed the road.

22nd mile. The eastern approach of the iron viaduct bridge over the Bagmati river was pushed westwards and raised. The screw pile bridge over the Perocha gap collapsed and the approach parapets were damaged.

23rd mile. The Benibad tubular bridge was heavily damaged. The masonry on both approaches on which the bridge was suspended collapsed and the abutments and all the piers were cracked. The iron frame lay suspended in the air. The metalled road was cut by fissures. The arches of the MB. 25 were cracked and its wings damaged.

24th mile. The re-inforced brick slab on the top of the "Irish culvert" was cracked and the culvert rendered unsafe for heavy traffic. Several fissures intersected the metalled road.

25th mile. The screw pile bridge collapsed. Several fissures traversed the metalled road, which sank in two places. Wells were filled with sand in the villages along the roadside.

26th mile. The arches of the masonry bridge, just east of the causeway, were cracked. There were several fissures in the neighbourhood.

Muzaffarpur-Pusa Road.—This road was not so severely damaged as was the case with several others within the same isoseist, since it lay outside the Slump Belt. Houses tumbled down along the first mile of the road, which was traversed by several large faulted fissures between the second and the third milestones. Paddy fields on both sides of the road became undulating. Heavy fissures cracked the metalled road at several places along the fourth mile. Within the fifth mile, the road sank at several places and was cut by large fissures. At two places, 30 and 20 feet in length respectively, the road sank about three feet. Dark sand was ejected sometimes over a foot in depth. Similar conditions prevailed up to the eighth mile and a little beyond. A *peepul* tree fell towards E.10°S. at the seventh mile. The masonry culvert together with parapets in the seventh mile cracked and sank and that in the next mile collapsed. In this mile about 45 feet of the road sank to a depth of four feet. Several fissures were present in the ninth mile and two arches of a masonry bridge at the next mile were cracked. From the tenth mile onwards the road was practically undamaged although occasional patches of sand

were noticed as far as the 16th mile. The Dholi masonry bridge, aligned E.35°S.-W.35°N., at the 16th mile, was damaged rather severely. A portion of the bridge was faulted towards the east and the eastern end near the abutment sheared horizontally and one of the arches sagged slightly. From here onwards the road was practically undamaged as far as the Pusa Research Institute.

Darbhanga-Madhubani-Jaynagar Road.—Sanding was very slight as far as Sakri. Most of the bridges were unaffected but occasional diversions had to be made on account of the cracking of a few piers. Sanding was slight on the way to Madhubani but it became very heavy at that village.

Darbhanga-Samastipur Railway.—All the observations were made from a running train. In general the railway lines were not so severely affected as in other places. Mileages refer to distances from Samastipur.

0-1 mile. Slight damage. Masonry bridge near 0/8 not seriously damaged.

1-2 miles. Not much damage.

2-3 miles. Gandak bridge displaced and lines buckled. At 2/9 lines were taken out. Heavy sanding in Muktapur station compound and yard. Lines buckled very badly. From here to mile 3 heavy sanding on both sides of the railway embankment. Cracks ran north-south and N.W.-S.E.

3-4 miles. Between 3-3/13 heavy sanding on both sides of the embankment, from 3/13-3/15 sanding only on the western side of the permanent way. From 3/15-3/21 fissures and sand vents on the eastern side. From 3/21-mile 4 sand vents and sand on both sides.

4-5 miles. From mile 4-4/12 sanding and some fissures. Between 4/12-4/16, no effects near the embankment but sanding in the distant lowlands. From 4/16-mile 5, moderate sanding. Fissures east-west.

5-6 miles. Heavy sanding from the fifth mile to 5/9. Then a region of no damage. Thatched huts in the distance were not much damaged.

6-7 miles. Bridge on road at 6/3 damaged, Kishanpur station was scarcely affected. Some of the *kutcha-pucca* houses were cracked and a few mud huts collapsed. North of Kishanpur station a number of cracks three to six inches wide ran in east-west to E.N.E.-W.S.W. directions. Sanding on both sides between 6/23-mile 7.

7-8 miles. Sanding between 7/2 and 7/9. Between 7/11-7/14 sporadic outbursts of sand. From here to mile 8 moderate.

8-9 miles. No damage.

9-10 miles. Sanding between 9/5-9/19.

10-11 miles. A diversion was made between 10/21 and 10/23 as the central pier of a masonry bridge collapsed and fell to the south, the girder and the rails hanging in the air.

11-12 miles. Some sanding between 11/10-11/13.

12-13 miles. Masonry bridge with girders damaged, 12/10-12/15 moderate sanding on both sides and from here to mile 13 heavy sanding on both sides of the embankment.

13-14 miles. From mile 13-13/2 heavy sanding on both sides of the embankment. From 13/2-13/10 the low land was covered by sand vents. The station building at Haiya Ghat was badly damaged having sunk over a foot, cracks on the station platform were parallel to its long axis, N.20°E.-S.20°W. The permanent way was buckled both up and down and sideways. The railway bridge near the station was damaged; the northern abutment was cracked as also were the two central pillars.

14-15 miles. The girder bridge between 14/13-14/15 was slightly damaged.

15-16 miles. Heavy sanding between 15/21-16. Piers of a masonry bridge at mile 16 cracked and a portion of the lines buckled up and down.

16-17 miles. Heavy sanding between mile 16-16/3. Sand vents near 16/23.

17-18 miles. Sanding and sand vents between 17/18 and 17/20.

18-19 miles. Masonry bridge between 18/9-18/10 only slightly damaged as also the one between 18/12-18/13. Sanding between 18/20-mile 19.

19-20 miles. Sanding between mile 19-19/3 and between 19/7-19/10. From 19/22 onwards both sides of the line were moderately to heavily sanded up to the approach of Laheria Serai station.

21-24 miles. Occasional sanding on both sides of the railway between Laheria Serai and Darbhanga.

Khagaria to Supaul via *Mansi Junction.*—The country on both sides of the railway line from Khagaria to Mansi, as far as one could see from a train, was not damaged by fissures or sand vents. From Mansi northwards, up to near the tenth mile conditions were definitely good—emission of sand was rare, the railway station at Badla Ghat, four miles north of Mansi, was not damaged. At about the ninth mile, the masonry bridge on the Kursela nala was damaged. The bedstone of the pier next to the north bank was shifted four inches to the north, the pier itself also moved about three inches in the same direction. In the case of the other piers the girders as well as the pillars moved three to four inches to the east. The railway lines on the bridge were buckled sideways. From milepost 10/10 northwards fissures appeared at right angles as well as parallel to the railway embankment. The girder bridge No. 44 on the Khagna at the 11th mile was affected rather badly; some of the piers leaned eastwards but the bedstones on them were shifted either towards the north or the south. The river flows here in an east-west direction and the bridge at this point is aligned north-south. The bedstone on the pier next to the north bank was pushed northwards, but those of the third, fourth and the sixth from the north bank shifted southwards. The following mileages refer to distances from Mansi Junction.

11-12 miles. Between 11/4-mile 12 occasional emission of sand. Cracks parallel to the embankment but no ejection of sand.

12-13 miles. Emission of sand rare.

13-14 miles. Occasional emission of sand in large patches from sand vents. Occasional cracks parallel to the embankment with no ejection of sand.

14-15 miles. Occasional sand vents in the borrow pits. Some cracks parallel to the embankment. At 14/13 mile-post the embankment

sank about four feet and emission of sand took place from vents in borrow pits.

15-16 miles. Medium sized sand vents in the surrounding lands with emission of some sand. Cracks parallel to the embankment between 15/5-15/7 mile-posts. At Semri Bakhtiyarpur cracks about half an inch to one inch wide ran parallel to the platform N.10°W.

16-18 miles. Rare emission of sand here and there.

18-19 miles. Occasional patches of sand especially in borrow pits.

19-20 miles. Occasional patches of sand, sometimes from crater-like vents. Land mostly clear. Sometimes a few cracks parallel to the permanent way.

20-21 miles. Occasional heavy emission of sand from innumerable vents. Cracks parallel to Sonbarsa Katcheri station platform aligned N.20°W. Much sand was ejected in the borrow pits.

21-22 miles. Heavy emission of sand took place.

22-23 miles. Moderate to heavy emission of sand. Sometimes the land was quite clear. At 22/10 there was a very large crateriform fissure.

23-24 miles. Emission of moderate to heavy amount of sand took place with intervening clear tracts. From 23/13 to mile 24 sand deposits were heavy, accompanied by large fissures.

24-25 miles. A practically clear mile. Occasional sand vents, with sometimes heavy emission of sand.

25-26 miles. Clear up to 25/5, then patchy sand deposits up to 25/8, from here onwards conditions much improved.

From Khagaria up to this point the tract lies in isoseismal VIII, from here northwards the entire line is in isoseismal IX. From Saharsa to Supaul the tract comes within the Slump Belt.

26-27 miles. North-south cracks were parallel to the asphalt paved platform at Saharsa station. The station was subjected to a moderate emission of sand which continued a few hundred yards north of the railway station. The station building was unaffected. Conditions became bad from 26/14-mile 27. Information was obtained from a Permanent Way Inspector, that at one place between Sonbarsa Katcheri and Saharsa stations the entire track with the rails, sleepers, ballasts, etc., was buckled sideways in an east-west direction. The maximum shift from the centre of the lines was between four to five feet.

The branch line of the B. & N. W. Railway from Saharsa to Matiali was badly damaged by fissuring. The embankment subsided and the lines were buckled as much as five feet laterally. At the Tilawa bridge, west of Baijnathpur station the girders fell and the brick piers were broken.

27-28 miles. Emission of heavy sand took place from mile 27-27/4 and then occasionally up to 27/8. Conditions improved from here up to mile 28.

28-29 miles. A fair amount of sand was ejected in patches.

29-30 miles. Conditions were bad on both sides of the permanent way. Between 29/10-29/11 a big patch of yellowish brown sand from a fissure running across the railway line in a N.W.-S.E. direction. Another big patch of sand was noticed on both sides of the line extending from 20/15-mile 30.

30-31 miles. Emission of sand took place on both the sides of the permanent way, more especially on the west. Clusters of sand vents were dotted all over the lines of several fissures, some of the latter having depressions near their centre.

31-32 miles. Occasional but heavy emission of sand took place. Sometimes it continued for several hundred yards. Sand vents were of two types—(*a*) a rim of sand around a depression or hollow, (*b*) crater-like. Fissures were of four types—(*a*) simple ground cracks ejecting no sand, (*b*) cracks with ejected sand, (*c*) fissures with sand and sand vents arranged in clusters along the lines of fissures, (*d*) crater-like fissures.

32-33 miles. Occasional patches of continuous dark grey and light yellow sand with intervening spaces of clear ground. The station platform at Panchgachia (32/12) was not cracked or damaged. East of the station, cracks were oblique to the railway track and some yellow sand was ejected.

33-34 miles. Emission of sand was pretty heavy up to 33/11, after which conditions improved slightly, but occasional patches of sand continued. Beyond 33/14 sand vents and fissures were confined mostly to the western side of the railway line.

34-35 miles. Wide fissures and some sand occurred.

35-36 miles. Occasional emission of sand. Conditions were distinctly better. The railway station at Parsarma (36/3) was not much affected.

36-37 miles. Emission of sand took place in the borrow pits. Sometimes fissures were present on both sides of the permanent way.

37-38 miles. Conditions rather bad. Patches of sand stretched for long distances on both sides of the railway lines.

38-39 miles. Emission of sand was less frequent.

39-40 miles. Portions heavily affected by sand emissions. Near mile 40 emission of sand in light patches.

40-41 miles. From 40/2-40/8 emission of sand rather heavy. At Dhimra bridge (40/9-40/10) some of the bed plates on the piers were shifted eastwards but that on the first pier from the north bank was shifted towards the north. From here onwards the land was mostly clear of sand.

41-42 miles. Emission of sand occasional but from 41/10 very rare.

42-44 miles. Emission of sand in patches, which became less and less approaching Supaul. A large crack at the southern end of the platform at Supaul emitted some sand. The station platform was also cut by north-south cracks along its length. From similar cracks on the eastern side of the platform some sand was ejected.

Supaul-Sakri via *Bhaptiahi.*—The railway line around Supaul was badly damaged. The lines were twisted and thrown out of alignment as much as three or four feet. Embankments sank in places two to three feet. Piers of bridges leaned towards the west, and in the case of girder bridges on brick piers, the steel plates on which the girders rest were displaced towards the west. At Tharbitia about eight miles N. N. E. of Supaul, a *pucca* house and one or two mud huts collapsed, most of the other mud huts were cracked. Conditions became worse on the line from Bhaptiahi to Sakri. Although the bridge between Raharia and Nirmali did not collapse, its piers sank and rendered the bridge unsafe for sometime. The lines were twisted and the embankments sank at many places.

Madhipura-Supaul Road.—Fissures and sand vents were abundant from near Gamharia into Supaul. The majority of the fissures were aligned N.E.-S.W. Many of the mud or bamboo and mud houses on both sides of the road collapsed, especially the mud huts. Fissures were more numerous on the Madhipura side of Supaul than on the northern side.

Mahadeopur Ghat-Katarea via *Bihpur.*—The rail lines from Mahadeopur Ghat to Thana Bihpur showed little signs of the earthquake. Thana Bihpur station, a *pucca* brick building, was undisturbed but adjacent buildings showed slight cracks. A planter's bungalow at Bihpur was rather badly affected.

Along the line to Karhagola Road station, there was no sign of damage to the stations. Some buildings adjacent to the line at Kharik were, however, badly cracked, and the upper portions of buildings—copings, parapets, etc., collapsed. Some of the movements here were definitely north-south. The railway bridge at Katarea appeared unaffected.

Karhagola Road-Purnea.—A good motorable road connects the two places. Proceeding from Karhagola Road there was no sign of damage up to Korha, at about the 15th milestone, where some buildings were damaged ; but the road and the surrounding country was much fissured and small areas of ejected white sand could be seen scattered about. In the vicinity of the road the majority of the fissures were more or less parallel to the road. The road subsided at many places and became very uneven. A screw pile bridge was not only slightly out of alignment but also sank a little in places. The earthquake damage became much more noticeable from about Chathariapir northwards.

Railway between Purnea and Jogbani.—Damage to the railway lines commenced about two miles south of Purnea. North of the town bridge abutments were cracked, and up to Forbesganj the brick piers sank in places. Between Purnea and the next station Kasba, the embankment sank in several places. The piers of the bridge near Kasba were out of plumb and sank. The abutments of another bridge near Kasba were shattered. North of Kasba the lines were buckled considerably and fissures ran east-west. From Kasba to Jalalgarh station there was no damage to the permanent way. From Jalalgarh to Kusiargaon station the embankment settled here and there. From the last station the damage to the permanent way became worse as the Araria Court station was approached ; bridges were shattered and fissures, although irregular, mainly ran parallel to the railway lines. The station building at Araria—a *pucca* structure—was badly fractured and had to be partly dismantled. From Araria northwards damage was still worse. Masonry bridges subsided, abutments were shattered, piers

sank and the track was crossed by innumerable transverse fissures up to half a mile long, whilst others were parallel to the track. The worst damage on this line took place between Simraha station and three miles north of Forbesganj station. The track beyond Forbesganj was very badly damaged. A bridge, two miles north of Forbesganj, was badly shaken; the brick abutments and the piers subsided ten feet almost to the ground level. Three miles south of Jogbani Station the piers of a girder bridge were tilted and the girder fell—the piers were 70 feet high and the tilt was up to 1 in 25. The badly built station quarters at Jogbani tumbled down.

Purnea-Murliganj (Isoseismal IX).—The piles of the Saura bridge were raised or lowered differentially. Pile bridges beyond sank slightly. The track subsided and the rails were so badly buckled that it was impossible for a trolley to go over them, at least as far as the Kali Kosi, five miles west of Purnea. At the Kali Kosi bridge the piles were moved bodily along the stream. Subsidence of the track and buckling of the lines continued from here up to mile 12, and fish-plates in some cases were sheared and separated as much as 12 inches. In some cases the track was buckled five feet, *i.e.*, thrown five feet out of alignment from the centre line. Buckling was noticed chiefly on or adjacent to a bridge. East of Sarsi the piles of the bridge sank. The railway station was badly shattered and the platform overrun by fissures. The pile bridge near Banmankhi, beyond Sarsi, was humped up and the adjacent track subsided. Buckling and subsidence of tracks and the derangement of the piles out of line continued right through to Murliganj. On this section most of the fissures were East-West even where there was no depression or embankment. Similar conditions prevailed over the Behariganj section up to Behariganj.

Purnea-Dhamdaha Road.—Dhamdaha is a small village about 20 miles Southwest of Purnea, with which it is connected by road. Fissures and sand vents were within ten miles west of Purnea, after which they were rare. The abutments of most of the bridges were cracked. About two miles west of Dhamdaha a timber pile bridge was humped up and the banks closed in a little.

At Dhamdaha the bungalows were slightly affected by wall cracks. Most of the bamboo and thatched huts remained undamaged.

The railway bridge a few miles out of the village had temporary sleeper piers at the date of inspection, as the timber piles were out of line.

CHAPTER XIV.

ISOSEISMAL X, NORTH OF THE GANGES.

Champaran district.

A small part of the north-eastern corner of Champaran district falls within isoseismal X. The only important village is Dhaka about 20 miles W. N. W. of Sitamarhi, where most of the huts collapsed and the thana was badly damaged by an east-west fault.

Muzaffarpur district.

Riga (26° 36′ : 85° 24′).—This station, situated on the B. & N. W. Railway and about six miles north-west of Sitamarhi, is the most westerly important place within isoseismal X. Many houses in the village collapsed and a large number were badly damaged; two bungalows sank about 18 inches. The railway lines were severely damaged, partly as a result of surface fissures many of which showed differential movement. The rails were buckled and twisted, and sleepers displaced about six inches, usually to the E. S. E.; the rails were broken at the fish-plates and telescoped, with also a lateral displacement of six inches. The road was badly damaged; cars on the road near Riga were stranded in sand, which locally reached a depth of three feet.

The most important building here, the Belsund Sugar Factory, was almost entirely ruined. Sand issued from fissures in the reinforced concrete foundations. The compound, which was 1 foot 6 inches above the surrounding country before the earthquake, sank on the average 1 foot 4 inches below the general ground level. Instrumental levelling, carried out a month after the earthquake, demonstrated differential movement up to 2·5 feet within the compound itself. The eastern wall of the compound showed a differential sinking of 1·5 feet.

Sitamarhi (26° 35′ : 85° 29′).—Sitaṃarhi is a sacred place in Hindu mythology, as tradition relates that here Sita sprang to life out of an earthen pot into which King Janaka drove his ploughshare. It is the headquarters of the subdivision of the same name and has a population (1931) of 10,701. The town is situated on a branch of the B. & N. W. Railway, and is also connected by road with the Nepal frontier, Darbhanga and Muzaffarpur. The Lakhandai river passes the eastern side of the town, and was spanned by a fine brick bridge.

Sitamarhi was the worst affected town north of the Ganges and came within the main slump zone. The town was badly damaged by fissures and sand vents and the greater part of it was covered with sand, in places four to five feet deep—sanding reached a maximum in this locality. According to Mr. Jalil, the second officer, some bullocks were trapped and buried under five feet of sand. All the wells in the town were infilled with sand but on re-excavating there was very little change in the water level. A well in the dak bungalow compound was crossed by fissures striking E. 10° N., causing differential movement of arches between the two halves of the well. Many fissures were parallel to streams, or to embankments, but others ran in a general N. N. W. direction. A typical fissure was 80 yards

long, eight feet wide and infilled with sand to within three feet of the top. Subsidence between fissures sometimes took place. The main drain running through the centre of the town was entirely choked with sand.

Although the town is placed in isoseist X, the actual collapse of houses, in the sense of tumbling to the ground, was not excessive; not nearly so marked in fact as at Monghyr. Houses collapsed largely as a result of the foundations giving way, but the number of complete collapses was small. Only one house, however, of any weight escaped tilting and sinking into the ground—the P. W. D. bungalow was the only exception—and none was inhabitable. Many of the walls of buildings sank as much as two feet and foundations and floors were broken up completely. Sand covered the floors of sunken buildings to a depth of up to three feet. Concentric fissures formed in the ground around several buildings.

According to Mr. Jasewal, Engineer of the District Board, the buildings on the whole were tilted radially outwards from the centre of the town. Buildings in the jail were left tilted as if on waves; portions collapsed and one of the block houses sank. The northern and southern boundary walls of the jail compound, two feet thick and of excellent brick construction, each fell north as a single unit. The eastern and the western boundary walls were cracked and left standing. The prisoners escaped, but one man returned in an *ekka* because the jail appeared to him safer than the bazaar. Fissures striking E. 12° S. traversed the jail compound which was full of fine sand. The jail is aligned E. 10° S.

The *kutchery* buildings sank three feet into the ground below their verandahs. The Criminal Court, a one-storey *pucca* building elongated N. 10° E. and surrounded by a verandah with arched roof, sagged in the middle. The eastern and the western walls were heavily cracked; the southern wall fell southwards; the north-eastern corner of the verandah fell to the north; the arches of the western verandah fell W. 15° N., and the pillars of the east-west verandah, together with the verandah, fell 10° E. of N.

The railway bridge collapsed as if pushed from the east; the piers fell west and the lines were severely twisted and buckled. At one place the ballast was pushed W. N. W. by the sleepers as much as a foot. The railway embankment subsided irregularly and large fissures were formed in the ground parallel to the embankment.

The Post Office clock stopped at 14·15 hours (I. S. T.) but the postmaster thought that the movement began between 14·11 and 14·12 hours (I. S. T.). The Post Office clock might have been a little inaccurate. The chairman of the municipality believed that the time of arrival of the shock was 14·15 hours (I. S. T.). According to him the shock was preceded by preliminary tremors, which increased in violence and ended abruptly. It was heralded by a loud rumbling noise.

Darbhanga district.

Madhubani (26° 22′ : 86° 05′).—This small subdivisional town (180 feet above sea level) in Darbhanga district is about 23 miles north-east of Darbhanga town and 25 miles from Laheria Serai, the district headquarters, to which it is connected by railway. It had a population of 18,789 at the 1931 census and is an important trading centre for the surrounding rich agricultural country. The town follows the north and south trend of the principal thoroughfares,

Madhubani was the most severely damaged town next to Sitamarhi; the type of damage was similar as the majority of the buildings were affected by slumping of the ground although a large number were damaged by severe shaking. Many of the buildings were tilted. Although in general most of the confused mass of bricks, plaster and splintered beams represented the remains of houses built of poor materials, the destruction of newly built *pucca* buildings testified to the strength of the shock in this epicentral alluvial area.

Within the town, over 80 per cent. of the buildings either collapsed or were badly damaged. Ground fissures ran through some buildings fracturing the walls and foundations and also causing subsidence. The heaviest damage was sustained in the bazaar area, where two-storied *pucca* buildings were the worst affected. Only a few buildings in Balna on the main road, to the south-east of the Barabazaar area, escaped any serious damage; this portion of the town also escaped sanding.

The railway station was not affected to the same extent as the town itself but houses near the station in the Suratganj area were badly damaged on account of subsidence and tumbling. A portion of the town west of the railway station subsided.

The eastern, southern and western portions of the town were overrun by fissures and isolated patches of sand vents, the northern part appeared to have been free from fissuring and sand. Most fissures had an east-west alignment but a north-south trend was not uncommon.

Local residents remarked that the shock came from a northerly direction—slightly west of north. Buildings were seen to sway in a north-south direction. The shock was accompanied by a terrific rumbling noise and was so great that many people were knocked down and few were able to stand without difficulty.

The main shock is said locally to have commenced between 14·10 and 14·12 hours (I. S. T.). The station clock stopped at 14·12 hours (I. S. T.). The duration was variously estimated at between 120 and 180 seconds.

Eye-witnesses gave the following accounts :—Mr. D. N. Raha, manager of the Rajnagar estate, was in the dak bungalow at Madhubani, and at about 2·15 p. m. he felt first a mild tremor followed by a smart shock and heard a rumbling noise as of distant thunder a few seconds after the first tremor. The duration of the entire shock was about three minutes but the main shock lasted about two minutes, the main shock ceasing abruptly. During the main shock he felt that a wave was passing below his feet and he was forced to sit down. He saw the tiles and walls of the building crash. Although buildings swayed north-south he noticed that the direction of the wave motion was in a general east-west direction. Soon after the shock had ceased water flowed from the causeway nearby. He ran to the railway station, which lay east of the dak bungalow, and found the railway lines undulated and thrown into S-like curves. At some places the permanent-way was raised and at others it had subsided. He then proceeded towards Rajnagar, following the railway line, and noticed numerous water spouts in the fields on both sides. The alignment of these was roughly parallel to the railway embankment and the water had a putrid smell. The colour was blackish with suspended sand and clay. He had to wade through the water occasionally and found it tepid warm at two places but mostly cold. In some places the railway lines were bent in zigzag fashion and were suspended in mid-air, the embankment having subsided;

the bridges were like inverted Vs. Mr. W. G. Archer, subdivisional officer, Madhubani, recorded two shocks at intervals of ten minutes; he thought the main shock, which started at 14·15 hours (I. S. T.), lasted for 120 seconds. Hanging objects fell in all directions but mostly to the east and west. Bricks were projected from door and window lintels. Ground fissures varied from an inch to two feet in width. Sand was deposited on either side of fissures as the water oozed out. Beds of tanks were raised and the river swelled. Mr. Bibhuti Bhusan Dutt of G. M. S. S. H. E. School, who was sitting on a chair in his office, felt three separate shocks, and was actually pushed up from below. He thought the shock began at 14·13 hours (I. S. T.) and lasted for 128 seconds, and that a rumbling noise, like that of an aeroplane or a motor car, commenced a few seconds before the shock was actually felt and lasted throughout the quake.

Some of the affected structures may be briefly described :—

The Criminal Court, a long one-storey *kutcha-pucca* building, is aligned 5° south of east to 5° north of west. The main east-west walls sank in the centre; all walls were cracked. Verandah roofs were displaced, in part, and one part collapsed.

The remains of the buildings were demolished by sappers and miners after the earthquake. The site was overrun by numerous ground fissures striking in a north-south direction. Numerous sand vents were present in the low lying ground west of the buildings.

The Bar Library was shattered by numerous ground fissures, all four walls being equally damaged. Portions of the roof collapsed and a large portion of the east-west verandah on the north collapsed.

The Dutt Medical Hall, a well-built two-storey building, aligned north-south, sank bodily, with a tilt towards the west and north-west but the walls were not severely cracked.

Rai Bahadur Sushil Kumar Roy's house, a two-storey *pucca* building aligned 10° east of north, was badly damaged and both the north-south and east-west walls were badly cracked. The second storey of the northern portion of the house collapsed completely. The main building sank a few inches into the ground. A portion of the house on the south-eastern corner collapsed as well as a portion of the first floor in the north-eastern corner of the main building. Portions of the roof on both sides came down. North-south fissures in the compound split the east and west boundary walls.

Kishori Lal's house is a large two-storey newly-built rectangular *pucca* building aligned east-west and with a central courtyard. Two ground fissures striking east-west opened the north-south walls on both sides, leaving gaping cracks six to nine inches wide. The central courtyard subsided, but the floors were raised and heavily cracked. The east-west walls were comparatively undamaged beyond a few minor cracks. A very wide crack three to four feet wide ran east-west along Rahika road in front of Kishori Lal's house, Naya Bazaar. Almost every house aligned east-west on both the sides of the road collapsed. The main crack noticed in Kishori Lal's house ran southwards first in a N. W.—S. E. direction and then swung round north-south.

Khemdhari Singh's house is an old fashioned residence of *pucca* and *kutcha-pucca* construction. The central portion—a two storey building—collapsed. Portions of the walls which did not fall showed heavier cracks in the north-south

walls than in the east-west. Two masonry pillars near the temple entrance east of the main building fell in a direction 10° east of north. The suite of buildings west of the main building collapsed.

The house of the widow of Babu Soni Lal Shah is of two parts: the eastern portion is an old *kutcha-pucca* structure, and the western is a newly built *pucca* building. The new portion—absolutely unaffected—was perhaps the only house in the town which escaped undamaged.

At Madhubani railway station the platform is aligned north-south. The station platform was cracked and sand and water was emitted. The booking office was badly cracked. The north-south walls were only lightly cracked in comparison with the southern east-west walls; the east-west wall on the north sank about half an inch. The other rooms of the station had slight cracks in north-south walls.

Rajnagar (26° 24′ : 86° 10′).—This small town is about six miles north-east along the B. & N. W. Railway from Madhubani. Apart from the beautiful palaces and gardens of the Kumar Sahib of Darbhanga, the town possesses no important buildings. All the *pucca* structures were seriously affected by subsidence, fissures and sand vents. The palace and office buildings of the Raj Estate were shattered beyond repair. Towers fell and gaping cracks, through which one could walk without difficulty, cut the walls of the various buildings in the palace grounds. Portions of the buildings collapsed and sank. The floors of the main palace were raised and cracked and the rooms flooded with sand and water. The State road leading to the railway station was faulted and fissured; at many places embankments sank to the level of the surrounding low lands and a screw pile bridge along the road was buckled up and down. Sand vents and crater-like depressions of very large dimensions were found on both sides of the road. The railway bridge north of the railway station practically collapsed.

According to Mr. R. L. Biswas, station master, Rajnagar, the shock commenced at 14·10 hours (I. S. T.), and lasted about 150 seconds. One smart shock of moderate intensity was followed by several sharp and severe ones in quick succession. The first shock was preceded by a deep rumbling sound as of distant thunder and the quake was accompanied by a high rattling noise as of an old motor car. Water and sand spouted at innumerable places, even gushing out from strong cemented floors eight feet above gound level.

The details of the damage effected at Rajnagar are as follows:—

The main building of the Rajnagar palace is aligned 5° east of north. The palace garden has a large tank on its eastern side. Damage to the building was largely by gaping cracks which mostly ran north-south and which extended from the roof to the ground and along which there was sometimes vertical displacement. Several rooms on the first floor collapsed; all three main towers were badly cracked and the dome of the central tower collapsed. A general sinking of the palace was noticeable, especially on the western side, where the adjoining verandah sank two feet. In the compound to th[illegible] of the main building a marble fountain, which was free to fall in any directi[illegible]ll towards 10° west of north. The garden path sank between two and three feet and was submerged by water which overflowed from the tank. The compound was strewn with sand craters.

North-west of the main palace the *pucca* house of the Maharajah's step-mother was reduced to a heap of debris. Three of the corner turrets fell south-west, but that on the north-east corner fell towards the east.

The bell tower on the south side of the Shiva temple, which is south-east of the main palace, collapsed as also did the tower on the top of the *lingam* (phallus), just near the entrance to the temple. The main tower did not crack. The building sank near the centre and the entire temple leaned almost due north. The north-south boundary walls were heavily cracked and tilted and effects of horizontal shear were noticed; the east-west walls were also cracked.

The head office, a massive, well-built, beautifully planned *pucca* structure, was entirely ruined by gaping cracks in the walls, subsidence taking place on the north and south sides of the building. The tower on the north side collapsed to the east and north.

The Girija temple, to the north of the head office, partly collapsed and the temple was tilted to the north. Ejection of sand here was considerable. In the Kali temple, built of white marble, verandah pillars were displaced as much as two inches, and the courtyard slabs cracked and displaced. Ground fissures here extended east-west.

The State manager's house is aligned north-south and sank on the eastern and southern sides; all walls were cracked, and sand and water ejected. The tube well in the compound was raised two feet.

The Rajnagar railway station withstood the shock rather well, but the railway bridge to the north of the station collapsed. The bridge had five piers in the river bed but the abutments closed in north and south with movement of the river bank and the four northern piers were tilted northwards; the pier near the southern bank fell and the steel girders were thrown into the river. As far as the eye could see both north and south from here railway lines appeared to be buckled laterally and vertically.

Mirzapur (26° 24′ : 86° 09′).—In this small village west of Rajnagar almost all the *kutcha-pucca* buildings collapsed as also many thatched huts. As at Sitamarhi, many of the *kutcha-pucca* buildings sank. Sanding was heavy, up to three feet deep. The screw pile bridge connecting the village with Rajnagar was buckled up and down.

CHAPTER XV.

ISOSEISMAL X, SOUTH OF THE GANGES.

Monghyr district.

Monghyr (25° 23′ : 86° 28′).—This very old town, on the south bank of the Ganges, is a district headquarters and, in 1931, had a population numbering 52,863. It stands both on alluvium and on a promontory of Archean rocks around which the Ganges meanders.

The town may be divided into two portions : (*a*) the Fort, which includes within its confines the government and other public buildings and the residences of most of the Europeans, and (*b*) the Indian quarters extending to the east and south. The Fort, built on a quartzite ridge, is formed of a great rampart of earthwork faced with stone.

The devastation in Monghyr was greater than in any other part of Bihar. The entire town was reduced to ruins, scarcely a house or hut escaped destruction or damage. In the Chauk section of Monghyr bazaar, which revealed the most spectacular havoc in the earthquake area, scarcely a building or wall was left standing. The remainder of the bazaar was not so seriously affected but nevertheless the damage was great. The number of casualties was so great that for several days after the earthquake the dead and the dying lay within the mass of bricks and debris. Although this large bazaar near the Fort was practically razed to the ground, the adjacent north-west corner of the town within the Fort, suffered but slightly. The main damage to *pucca* buildings occurred at the edge of the high ground, on the alluvium along the eastern side of the Fort. Here, all the buildings were destroyed. The Fort wall collapsed in many places. Ground fissures cut right through the massive walls of a bastion on the west side of the Fort, at the edge of the river.

The general direction of movement throughout Monghyr was east to west, but vertical movements were also noticed ; instances were quoted of buildings being lifted a few inches before they collapsed. Rotational movements were also indicated by the monuments in the cemetery.

Although a few ground cracks appeared here and there the wholesale fissuring and sanding of the slump belt was noticeably lacking at Monghyr. According to a report from Chupraon factory a huge spout of water several feet in diameter rose quite high into the air in front of the garden ; the water so saturated the ground that the garage some 200 yards from the spot sank. North-east of Sitakund, four miles east of the town of Monghyr, three *bighas* of land were covered to a depth of up to six inches with a sandy silt ; there were four fissures running east-west on the north side of a shallow stream, and water was said to have spouted to a height of four feet during the quake.

As a rule, buildings on rock outcrops were damaged less than those on alluvium. The quartzite forming the higher ground appeared definitely to have resisted the severe shaking and the greatest damage was confined to the alluvium immediately

surrounding it. The Pir Pahar house may be cited as an example. The house is built on the quartzite hill to the east of the town ; a portion of the eastern verandah collapsed, otherwise the building was only slightly cracked. This type of building was almost invariably badly damaged elsewhere, the rich ornamentation, roof balustrades and verandah pillars collapsing. Other buildings which escaped included (1) new brick-and cement-built houses, as the Lochnagar bungalow, (2) those built on eminences or platforms, which acted as cushions and (3) cement concrete or re-inforced concrete structures, such as the Electric Supply Company's power house and offices.

Most of the houses along the river front, particularly on the north-west side of the town, suffered less damage than those elsewhere, and many were subsequently quite habitable, even though they were on alluvium. This was in contrast to the damage at Patna. In the case of a town such as Monghyr, where an almost wholesale collapse of buildings took place, it is difficult to single out individual buildings to convey an idea of the type of damage effected, hence only a few of the damaged buildings are described here :—

The Judge's house was slightly damaged and the house of the Kasim Bazar family, built on rock on the river bank was slightly cracked. The movement here was in all directions. The eastern side of the Deputy Commissioner's Court fell mostly to the east, and the remainder of the building was badly cracked. The Subdivisional Magistrate's Court partially collapsed on the northern side ; the western and southern portions were standing but badly cracked. The Collectorate building was very badly damaged ; both the roof and the walls partially collapsed. The Judge's Record room was affected only over doors and windows. The jack-arched roof of the Treasury building was badly cracked. The verandahs on the south and the east sides of the Civil Court building were badly damaged, the pillars were out of plumb. Of the two Record rooms, the newer one suffered only slight cracks whilst the older, which was a tall building, had larger cracks. The Police office was badly damaged ; only two rooms on the south were spared. The Police Station collapsed. The Town Hall was badly damaged and the outhouses forming the servants' quarters fell. The P. W. D. godown collapsed. The Jail buildings were badly damaged and the prisoners had to be secured in a shed under an armed guard soon after the earthquake. The jail walls fell east and north. The eastern and western ends were built on top of the old wall which was eight feet high ; the upper part collapsed at the join. The Jailor's quarters and office collapsed completely and the Assistant and the Deputy Jailor's quarters collapsed partially and portions were seriously damaged. The remaining buildings in the jail were variously damaged. Monghyr church collapsed as also did the western wall of the church compound. The Collector's and the District Judge's residences were two of the very few building in Monghyr which escaped with minor damage ; the main buildings escaped with slight diagonal cracks in the walls and over the arches. The outhouses were, however, more severely damaged. The Civil Surgeon's residence was badly damaged and had to be rebuilt. The residence of the Superintendent of Excise collapsed, killing his two daughters. The residence of the Police Superintendent collapsed and the Superintendent of Police was injured. In the Monghyr Hospital only the lower storey of the women's hospital was undamaged. The Baptist Mission collapsed. The gate here gave excellent evidence of the acceleration ; an ornament on the top of the south gate post fell south, the north gate post fell

bodily east and the fracture near the base was such that the post could not have moved laterally before falling. Only slight damage took place at the Monghyr Water-works; the tower was undamaged, there were some fine cracks in the masonry of the overhead tank and the suction pipe of one of the pumps became choked. A settling tank leaked on account of cracks in the walls. There were some leaks in the mains but they were speedily repaired and the supply of water was resumed within a short time. The Superintendent's quarters were badly damaged. The Electric Supply Station, built of concrete, was undamaged. An electric fan suspended from a low ceiling in the Electric Supply Co.'s new premises—intact building—struck the ceiling at both the extremities of its swing in a roughly east-west direction. Two blades of the fan were bent. The factory of the Imperial Tobacco Manufacturing Co. (India), Monghyr, is a modern brick structure with a steel framework. The shock here was felt distinctly in a N. E.—S. W. direction, followed by rotatory movements of the ground and then by an up and down motion. Twelve feet of the top portion of the brick chimney fell to the east.* The brickwork was fractured and the steel frame work of the building thrown out of alignment. The western wall was leaning west and the movements of the roof joists resting on the walls fractured the latter. The steel window frames were buckled, but wooden frames were undamaged. The tomb of Shah Nafa, an old monument built on a low hillock, completely collapsed. The Fort wall, built in Moghul times, collapsed in many places.

In the Chauk section of Monghyr bazaar, over an area of some 40 acres, every building was razed to the ground. Over a larger area of the bazaar, the narrow streets and winding lanes were blocked for several days by the debris from fallen two-storey buildings. It was impossible to distinguish the gullies and even the wider roads, as debris of the ruined houses covered everything. Considering the extent of the destruction it is surprising that only some 1,200 people were killed; this comparatively low casualty list is explained by the fact that actual collapse of the buildings took place towards the end of the shock, permitting people time to get out into the open. Deaths were mainly amongst women and children who were unable to get out of doors quickly. The widespread damage in the bazaar area results from the number of tall, old and badly built structures which occupied this section.

A large number of private buildings outside the bazaar were also ruined, amongst them being the palace of the Raja of Monghyr and a number of old buildings of historical interest.

Outside Monghyr there was little sign of damage to the mud huts in the various villages. Only those provided with heavy tiled roofs were damaged. Usually, in such cases, the roof collapsed bringing down the walls.

In the Old Cemetery, the top of the obelisk over William Mundy's grave was cracked, apparently by east-west movements. Two other columns and another obelisk were cracked by east-west movements A tall round column on a square base fell towards the north-west. In the New Cemetery, the headstone over Allen

* Same direction as a chimney at Bhagalpur which came down on the engine house roof to the east.

Dear Murray's grave rotated anti-clockwise, whilst the lower part of the base of the headstone of Herschel Dear Murray's grave and also another similar headstone rotated clockwise. A marble obelisk fell to the east; another similar obelisk fell south and its base rotated anti-clockwise. The top portion of an obelisk was standing but it had moved westwards, whilst the base was twisted anti-clockwise and moved five inches towards the west; the pedestal was intact. A cross, facing east, fell north and rotated clockwise as it fell. Several brick monuments were cracked by east-west movements. Most of the monuments in these cemeteries were facing east and west.

CHAPTER XVI.

ISOSEISMAL IX, NORTH OF THE GANGES.

Saran district.

Villages in Gopalganj and Chapra subdivisions.—In the villages of Gopalganj and Chapra subdivisions, huts were destroyed by large ground fissures from which sand and water were ejected. Some of the individual cracks were several hundred yards long, three to four feet wide, and one was reported to be over 30 feet deep. Evidently this formed part of the Slump Belt, which crossed the Gandak river into the Saran district where it extended in a N. W.–S. E. direction for over 30 miles parallel to the Gandak river over a width of ten miles. Many villages within this zone were badly affected by fissures and sand; others built on raised ground escaped fissuring but were severely shaken and innumerable mud huts collapsed.

Villages affected by sanding and fissuring include Rajaputty, Marwa, Satjora, Sahbazpur, Dubauli and Murwara. Wells and *nalas* were choked with sand and, village sites were destroyed by large fissures. At Rajaputty the bungalows of Miss Rutherford were extensively damaged by large fissures and the floors of some of the rooms were raised as much as six inches by outbursts of sand. A shallow tank in the compound was filled with sand to a depth of a foot and a half. At Sahbazpur a chest containing ornaments was reported to have disappeared into one of the fissures which passed through a two-storey *kutcha-pucca* house, completely wrecking it. The old bed of the Gandak lying west of this village was said to have been raised and the District Board road skirting the village was thrown into undulations. Some bridges along this road were cracked and abutments raised as much as three feet.

Villages damaged by simple shaking include Tarwa, Devapur, Teinura, Faizullahpur, Sarangpur, Rasauli, and Phekuli. Sometimes heavy outbursts of sand took place in the low lands surrounding the villages, damaging the crops and, in the case of one or two villages, the ground level was reported to have been changed by the earthquake. The severity of the shock experienced by these villages could be gauged from the fact that the majority of the mud huts were practically razed to the ground.

Champaran district.

Motihari (26° 40′ : 84° 55′).—This town, the headquarters of Champaran district and with a population of 17,545 in 1931, is picturesquely situated on both sides of a lake, which at one time formed a part of the Gandak river. The town suffered severely during the earthquake and was isolated for some time owing to the destruction of railway lines and bridges. Many houses collapsed. Faulting, fissuring and emission of sand from innumerable vents were very extensive, particularly along the margin of the lake. Fissuring was pronounced on the polo ground. Most of the wells were sanded. Around the lake, subsidence took place by step faulting, one fault dropping the ground ten feet on the lakeward side. A

marked north-south fault zone which ran across the road near the Bank of Bihar, had a downthrow of three feet six inches to the west and was 30 feet wide but filled with sand. Houses in the proximity of this fault were bodily tilted. The Zilla school and the hospital were severely cracked ; at the hospital sand emerged through the floors which were arched into domes, and the roof partially fell. The north compound wall of the jail fell and parts of the main block were badly cracked. The Collector's house, an old building, was completely wrecked. Damage to buildings at Motihari was largely due to settling of the foundations. The town is included in the Slump Belt. According to Mr. Fergusson, Superintendent of Police, the earth movements were definitely east-west. He also refers to distinct thuds which he felt whilst sitting on the ground during the shock.

The foundations of the Court building gave way completely and the cement floors were broken up. Walls were severely fractured and sank as much as one foot relative to the floors. In places the lateral movements of the floors appeared to have been as much as three inches as indicated by cracks. The foundations of the Executive Engineer's bungalow gave way and the walls sank relatively to the verandah. At the Planter's Club, pillars were sheared by outward thrust of the roof towards N. 25° E. The club compound was flooded with sand. The Bank of Bihar was completely wrecked. The pillars of the verandah of the Zilla school were sheared by the thrust of the roof towards the south west. The top of the spire of a temple in the bazaar fell in the direction S. 50° W. The Motihari Factory is a brick building without a steel frame and the walls collapsed. The steel girders supporting the rust tanks bent over towards the north. The steel chimney did not collapse. The rails in the factory siding were badly twisted and the sleepers moved northwards about ten inches. Telegraph poles fell northwards. The well in the factory was filled with sand.

Sagauli (26° 46′ : 84° 45′). This village is nearly midway between Motihari and Bettiah, on the road to Nepal, and is on the north-western edge of the Slump Belt. There was here much fissuring and emission of sand. The water began to come up after the shock had subsided and continued to flow for three hours. Some of the houses in the village partially collapsed and most of them were badly cracked. In the sugar factory cracks occurred in the reinforced concrete foundations, which sank about three inches. The walls of the factory were badly damaged.

Gobindganj.—At this small village, about 19 miles south-west of Motihari, cracks were rare and the fields only slightly affected.

Sangrampur.—In this small hamlet on the Gandak river, about three miles south-east of Gobindganj, the houses were slightly cracked but much sand and water were ejected.

Kesariya (26° 21′ : 84° 53′).—This village is in the extreme south of Champaran district. The village was severely shaken ; a wood pile bridge was distorted vertically in the form of an arch and the ends driven bodily south for about nine feet over the roadway.

Pipra (26° 30′ : 85° 00′).—Close to the railway station on the B. & N. W. Railway, 13 miles S. S. E. of Motihari, is an old disused factory in which the pillars fell in a direction E. 15° N. One of them, 7½ feet by 2¼ feet by 2¼ feet, gave an acceleration figure of 2,943 mm. per second per second.

Mirpur.—In this small village, about 5 miles west of Dhaka on the road to Motihari, many houses collapsed.

Barachakia (26° 24′ : 85° 03′) *near Chakia.*—In recent years a large sugar works has been established at this village in the Champaran district. The land around the Barachakia Sugar Factory was not badly fissured but the building was very severely cracked. Three thousand cubic feet of sand came up through the foundations of one part of the building. The foundations, made of brick and cement, were not broken but moved as a single unit. Fourteen cast iron columns in the centre of the building cracked horizontally as a result of the inertia of the overlying wrought iron structures, which stood undamaged. The walls of the factory are of brick set in lime mortar. The east-west wall of the factory fell south and the north-south wall fell west. An E.N.E.—W.S.W. wall fell partly N. N. E. and partly S. S.W. Water in a large masonry tank swilled out to the north. The tall brick chimney of the factory fell W. N. W. Many of the bungalows here were scarcely affected. The movement was definitely recognised as east-west.

In this area about 1 per cent. of the country was damaged by sand.

Tetaria (26° 24′: 85° 12′).—This village is in Champaran district, between Motihari and Muzaffarpur, and is on the edge of a lake. The locality is in the Slump Belt, and sand vents and fissures were very numerous; 25 per cent. of the high land and 75 per cent. of the low land was covered with sand to a depth of three feet, and an average of 18 inches to two feet. In one place hard clods of dry silt 12 inches across were thrown out of the vents. Movements in this village were definitely east-west. The house of a sugar planter, Mr. Crane, on the east bank of the lake, subsided towards the lake and was completely ruined.

Muzaffarpur district.

Muzaffarpur (26° 07′ : 85° 24′).—This comparatively modern town, founded in the 18th century by Muzaffar Khan, is situated on the south bank of the Burhi Gandak and had a population of 42,812 during the 1931 census. The main town is on high ground along the southern side of two large lakes, Sikandrapur lake and Akharaghat lake, which are cut off meanders of the Burhi Gandak. The bazaar, the most thickly populated portion of the town, was situated on the south side of the Akharaghat lake. Some of the finest houses in the station were built close to Sikandrapur lake to the north of which is a fine *maidan*, a portion of which formed the polo ground. The principal thoroughfares run east and west.

The greater part of the town, north of the railway station, suffered very severely. The damage in the Purana Bazaar and its vicinity was appalling and widespread; the majority of the buildings collapsed either totally or partially. The buildings were mostly old and defective two-storey structures built of poor materials. The case was similar in the Kalyani area, Islampur Road, Kedar Nath Road and Narwai Bazaar. In Marwari Mahalla and Motijhil the damage was no less severe but a number of well-built *pucca* buildings survived the shock. Many buildings might have escaped if they had not been dissected by ground fissures. Here and there several *pucca* buildings escaped unscathed, the most noteworthy being the office and residence of the Inspector of Schools and the Apurva Nivas. The worst affected quarters were Sikandrapur, Chanwara (west and south of the Burhi Gandak respectively), Purana Bazaar, Marwari Mahalla and Motijhil. In these areas buildings were damaged by slumping and fissuring of the ground and by shaking. Fissures, from which fine grey sand and water were discharged, were

more or less restricted to a narrow zone west and south of the Burhi Gandak, between Sikandrapur and Chandwara, but were also present in the heart of the city. Most government buildings north of the railway station fared badly, some of them partially collapsed. Amongst the few buildings which withstood the shock were the Government Records Room (a well built one-storey building), the newly built Criminal Court, and the Town Hall. Immediately south of the Burhi Gandak, most of the heavy-roofed buildings situated on an east-west tract of land, either collapsed or were severely damaged; such buildings included the Darbhanga Raja's Juran Chapra Hall, the District Judge's bungalow, the European Club, Tejpat's house on Sikandrapur Road, the Kalikothi, the Collector's bungalow, Mr. Mahta's house at Chandwara and the District Jail. Here the main damage was due to slumping and fissuring of the ground. In several cases the sites were rendered useless for the erection of new heavy buildings. However, several one-storey structures with light roofs here, including the Post and Telegraph Office, escaped.

South of the railway station most of the one-storey *pucca* buildings were saved, such as the English Church, the Deputy Inspector General's residence, and the new Circuit House. The railway station was practically undamaged as also were some of the railway quarters and the buildings of the Public Works Department. No fissures of any magnitude were noticeable here.

The polo ground at Sikandrapur was intersected by parallel fissures striking approximately east and west. The fissures varied from a few inches to one foot in width. Nothing was ejected from them and none were very deep. The ground was faulted, with downthrow towards the lake to the south. Fissures in the compound of Darbhanga Raja's house, east of the polo ground, from which sand and water was ejected, ruined the entire building. From the fissures in Chandwara much sand and water emerged and the fissures were variably aligned from W. N. W.—E. S. E. to north-west and south-east. The fissures at Motijhil ran in a N. N. W.—S. S. E. direction, were one to two feet in width and ejected much sand and water.

Most of the wells at Muzaffarpur were choked with fine sand; tanks which were dry before the earthquake were filled with water which flowed in from the surrounding land, while others became shallower as their beds were filled with ejected sand and silt. The general water level appeared to have been very slightly affected.

As regards the time of incidence of the shock the most reliable information was supplied by the clock of the local telegraph office. The clock which faced west stopped at 14.15 hours (I. S. T.). The concensus of opinion at the post office was that the time of arrival of the first shock was between 14.13-14.15 hours (I. S. T.). The first shock was a tremor, which increased in violence, attained a maximum and died out abruptly. The duration of the quake was three minutes. The shock was heralded by a loud rumbling noise, which persisted during the quake.

The damage suffered by some of the principal buildings may be described:

All the arches in the portico in front of the Commissioner's Court were cracked. The western and eastern wall of the main *ijlas*, running north-south were cracked, as also were the walls in the other rooms. Only a few minor cracks appeared in the Criminal Court, a one-storey *pucca* building, about 2 years old. One of the few buildings to escape undamaged was the Records Room, a well-built, fairly tall one-storey *pucca* building with numerous supporting columns, in which old government records are kept. The Civil Court buildings consist of a row of

one-storey *pucca* buildings aligned north-south; the walls on the north and south sides came down. A large *ficus* tree in front of the Civil Court compound was reported to have swayed to and fro in a direction N. 20° E.-S. 20° W. The two blocks of the Civil Court, one-storey *pucca* buildings, largely collapsed. In the Collectorate, a one-storey *pucca* building, parts of the roof collapsed, the walls were cracked and somewhat displaced laterally. The roof of the Account Office collapsed. Portions of the roof and walls of the Imperial Bank collapsed and some of the east-west walls were leaning towards the south. The District Judge's bungalow collapsed completely, and the Collector's bungalow was badly wrecked and had to be pulled down. The Telegraph Office, an old building with roof of galvanised sheet iron, did not suffer much damage. The Post Office, a one-storey *kutcha-pucca* building, partly collapsed. At the District Jail part of the north boundary wall and the whole of the south boundary wall (350 feet long, 12 feet high and 20 inches wide) collapsed. The eastern and western boundary walls showed a horizontal displacement of two to three inches. Most of the wards were severely cracked; No. 5 Ward and the jail hospital collapsed completely, but the female ward was undamaged and the jailor's quarters only slightly cracked. All the objects in the manufacturing godown were overturned towards the south; the general direction of movement appears to have been north-south. During the quake the level of water in a large tank north of the jail rose to a height of three feet, and fishes were thrown up and down. A well on the north-western corner of the outer jail compound threw out sand and water and was filled with sand. Mohamad Ayub, the jailor, thought that the shock was in a north-south direction and that the time was between 14.10-14.15 hours and lasted for about five minutes. He compared the noise before and during the shock with that of a motor engine.

A zone of fissures, striking N.N.W.—S.S.E. passed through Sri Narayan Mahtha's two-storey *kutcha-pucca* house, Chandwara. The south-eastern portion of the building collapsed and the remainder, although standing, was badly shattered. A one-storey kitchen at the back of the house sank about two feet and a cook's stove disappeared in the fault zone. At this place water spouted to a height of eight feet from some vents and some *Paludina* and charcoal were also thrown out. The western north-south boundary wall was split by the fault and showed a vertical displacement of two feet six inches on the east side. The compound was flooded with sand and water thrown out from vents which followed the fault zone. The garden in front of the house was dissected by a zone of irregular subsidence with a cumulative downthrow towards the north-east of six to nine inches. On the road in front of the house, one of the fissures was 23 feet wide. In a dry nala to the east of Sondhi Bhavan, which was badly shattered, many sand vents were formed and the largest, an elliptical crater, was 25 feet long and ten feet wide. A chimney on the N. N. W. corner of the Water Works fell N. 15° E. The inside supporting pillars of the water tower fell N. 5° E. The banks of the river, immediately to the north of the works, were faulted longitudinally, the amount of throw being ten feet. Syed Muhamad Vakil's house collapsed. According to local legend two cyclists disappeared into a four foot wide fissure which ran along the road in front of the house. The southern and eastern wings of Kalikothi, a one-storey *pucca* building south of the lake, collapsed. About 200 yards south-west of the main building ejected sand and water rose to a height of four to five feet and knocked down a lad. The spire on the top of

the Clocktower in Purana Bazaar fell south and the clock fell to the N. 10°E. Apurva Nivas, a newly built, two-storey *pucca* structure escaped with minor cracks. The Juran Chapra Hall (property of Dharbhanga Raj), an old *pucca* building, collapsed completely. The European Club, situated on the southern edge of the lake, was a *kutcha-pucca* structure containing a large central hall with a galvanised sheet iron roof, and it partially collapsed. Tejpat's house, on Sikandrapur Road, is a massive newly built, two-storey, *pucca* building in three separate blocks connected by overbridges built on arches. The house had a verandah on its west which was supported on pillars. The arches of the overbridges opened, isolating the three blocks of buildings from each other. The northern and southern blocks were traversed by a wide east-west crack. The central block sank bodily about one foot. Darbhanga House, Sikandrapur, an old fashioned one-storey, *pucca* building was damaged partly by shaking but more particularly by ground fissures, which were here extensive. One of them was 300 yards long and six to eight feet wide in places and ejected sand and water. Where they had not collapsed the walls had gaping cracks in them. The main portico on the west collapsed and one of the masonry pillars fell towards W. 15° S. The flagstaff was tilted in a westerly direction. The pillars of the east-west verandah on the south were inclined either eastwards or westwards. At the Jackson Memorial Methodist Episcopal Church, one of the two gate pillars fell N. 22°-23° E. and a cross, on the portico in front of the church, fell W. 12° N. The probable distance of projection was seven feet. The roof of the Roman Catholic Church collapsed and the bell was flung from the belfry a distance of 15 feet a height of 20-25 feet in a direction N. 60° E. The Church of England was damaged by cracking and collapse of some ornamentations.

Mushari (26° 06′ : 85° 27′).—At this place, six to seven miles east of Muzaffarpur, there is a sugarcane research station, situated on higher ground adjacent to an old ox-bow of the Burhi Gandak river. A masonry irrigation channel running north-south was buckled up and down, the distance between the crests being 240 feet. The sugarcane crops were covered with thick deposits of fine micaceous sand to a depth of 1½ to two feet. Mr. Cliff of the research station was of the opinion that the sand was shallow in origin and came from a depth of less than 100 feet. One corner of the field slumped as much as four feet, due, probably, to the emission of sand from vents. There was no indication of any lateral shift or slip into the old ox-bow, since the fence between the field and the banks of the ox-bow did not move laterally. On the western side of an embankment distinct hummocks appeared in the ground.

The country on both sides of the road to Mushari was dotted with sand vents, fine micaceous and carbonaceous sands filling the *nalas* on both sides to a depth of three feet or more.

Sheohar (*Shiuhar*) (26° 31′ : 85° 18′).—This village, situated in the south-west of the Sitamarhi subdivision and three miles north of the Baghmati, was badly affected and comes within the Slump Belt. The Raja's palace collapsed. Mud huts, although standing, were heavily cracked. Pillars (12 feet 11 inches by 3 feet 0 inches) at the end of the bridge over the Lakhandai fell to the south and north.

Belsand (26° 27′ : 85° 24′).—This large village, situated on the east bank of the Old Baghmati about 27 miles north of Muzaffarpur, was badly shaken by the earthquake and is in the heart of the Slump Belt. Mr. Dobson's bungalow completely collapsed and slumped. The village was overrun by extensive fissures

and much sand and water emerged. It was reported that the water had a tem perature of a hot bath. In a neighbouring village, Atri, many mud huts collapsed.

Motipur (26° 18′ : 85° 12′).—This village, about 16 miles north-west of Muzaffarpur, owes its importance to an adjacent large sugar factory. The majority of structures at Motipur appeared to have fallen north and south. The new sugar works was not badly damaged and continued working after the earthquake. The mill foundations sank uniformly and not unequally, a total sinking of 15 mm. taking place. The roofs are of light galvanised sheets supported on brick walls. The N. N. E.—S. S. W. walls were badly cracked and the E. S. E.—W. N. W. walls fell towards N. N. E. The cross plates in the roof girders were bent. Many cracks developed later, on the night of 19/20th January. A 160 foot high steel chimney remained intact. The old sugar works collapsed. The bungalow was badly damaged.

Fissures ran all along the road, mainly striking north-west; sand vents were numerous and the ejected material varied from grey micaceous sand to fine silt. The railway lines and the bridge were severely damaged. North of Motipur, the northern end of a bridge was squeezed, pushing the arch upwards.

Darbhanga district.

Darbhanga (26° 08′ : 85° 54′).—This large town, with a population of 60,676 in 1931, stretches for five or six miles along the bank of the Kamla Nala in a north-south direction. The principal buildings form the residence of the Maharajah of Darbhanga.

The town was severely shaken by the earthquake but the damage was less than at Muzaffarpur and the destruction of buildings was not so wholesale. A very large number of buildings, particularly in the heart of the town, collapsed or were badly damaged. Quite an appreciable number of *kutcha-pucca* and *pucca* houses survived the shock remarkably well. In general, walls running from east to west fell and those aligned north to south were cracked, but in several instances the reverse was the case. The buildings belonging to the Maharaja of Darbhanga fared badly. The Nargaona palace was so badly damaged that it had to be pulled down; the Lachmiswar palace, Anandbagh, escaped with a few cracks in the walls and floors, but the clock tower of the palace was badly cracked and had to be dismantled; the damage done to the Rambagh palace, although extensive, was not severe, but the Treasury Building which adjoined it to the south was severely affected. Fissures were practically absent from the town itself but the polo ground was affected as also the compounds of the office buildings of the Darbhanga Raj; these buildings were affected by ground fissures in the same way as in Muzaffarpur. The worst affected area in Darbhanga town was Katki Bazaar; the locality was densely packed with two-storey *kutcha-pucca* and *kutcha* buildings which were almost razed to the ground, and few buildings escaped. In the Bari Bazaar area the devastation was not so extensive but a larger number of buildings suffered from the shock; several two-storey buildings were but slightly damaged, and a few escaped entirely. Although the Kamla flows immediately to the west of Bari Bazar it is remarkable that the site was undisturbed by any fissures. Details of the damage to some of the principal buildings are given:

The Rambagh Palace consists of a group of one-storey buildings separated from each another by rectangular courtyards; the length of the entire building is aligned N. 10°E. In general the palace buildings were affected only by occasional cracks, which were mostly in the southern walls of the main group of buildings. Some old cracks in the roof were re-opened but none of them were serious. A number of small turrets on the eastern parapet of the main building fell, mostly in a southerly direction. A turret on the western side fell towards W. 35°N. At the southern extremity of the palace a large brick dome was flung from the parapet, about 30 feet above ground level, to a distance of 12-16 feet in a direction S. 8° W. On the northern side the turrets fell in a direction N. 5° E. The east-west boundary wall fell partly towards the north and partly south. A well in the western compound was choked with sand and fine sand was ejected from several narrow fissures in the compound on the south-western side of the building. The old Treasury, situated at the extreme south of the Rambagh Palace, was heavily damaged; the building extended east-west. The roof collapsed, and for the most part the east-west walls fell southwards and the north-south walls were heavily cracked. Portions of the east-west boundary walls on the southern side fell either north or south and the north-south boundary walls were cracked. The central *kutcha-pucca* part of the Nargaona Palace, which consisted of several two and three-storey buildings, totally collapsed but the newer *pucca* buildings escaped with minor damage. Observers stated that the main building swayed in a north-south direction before the roof and the floors collapsed. A fissure, striking E. S. E., from which sand and water were ejected, cut across the building. At the Lachmiswar Bilas Palace, Anandbagh, a well-built, two-storey *pucca* building elongated north-south, the clock tower on the eastern side was heavily cracked and had to be dismantled. The clock stopped at 14.13 hours (I. S. T.). The palace is situated between two large tanks on its east and west. The compound between the palace building and the tank on the east was covered with a little sand ejected from vents and fissures. In the *durbar* hall the north-south walls were undamaged but the east-west walls and the rooms adjoining to the south, were badly cracked by narrow ground fissures which travelled up the walls and across the ceilings. The north-south corridor on the east was damaged similarly. With the exception of these cracks the entire building withstood the shock remarkably well. The central pyramidal tower of the Kali temple was sheared at the base by a diagonal thrust acting from the north, and the entire pyramid was pushed slightly to the south. The turret on the north-eastern corner of the roof fell in a south-westerly direction, that on the south-eastern corner fell S. 10°W. In the one-storey *kutcha-pucca* buildings of the Government Zilla School the north-south walls were severely cracked, the east west walls only slightly. Portions of the buildings collapsed, and roof arches were cracked. The Darbhanga Medical School was damaged more considerably on the south-eastern side. The E. S. E.—W. N. W. walls were damaged more considerably. The high walls of the Post Office, a one-storey, *kutcha* building, were cracked and there was partial collapse. The Post Office clock stopped at 14.17 hours (I. S. T.) and the postmaster was of the opinion that the shock came from the north-west. The Railway Station buildings had only minor cracks and a fissure ran north-south parallel to the platform.

Laheria Serai (26° 06′ : 85° 54′).—This comparatively newly-built town, the headquarters of Darbhanga district, is situated immediately south of Darbhanga town.

Damage was considerable, more particularly in two-storey structures; even such a well built structure such as the Civil Court could not withstand the shock. A large number of buildings in the bazaar area suffered, both on account of the shaking as well as by ground fissures. The road levels changed in places and sand was ejected from many of the fissures. Some of the affected structures may be described:

The Collectorate building is a one-storey *pucca* structure with verandahs on all sides, the offices of the Imperial Bank of India and the S. D. O.'s *ijlas* being located also in the southern block. Cracks developed in most of the walls. An east-west crack affected the north-south walls just north of the Collector's *ijlas* causing the junction between the roof and the east-west wall on the northern side of the Collector's room to cleave and the wall to lean towards the south, the horizontal shift being about three feet. The eastern portion of the northern block was more damaged than the western side. There were small collapses from the roof. Sand and water were ejected from fissures and small vents on the western side of the court compound. The Civil Court building was a well-built two-storey *pucca* structure aligned east-west and with two wings on its eastern and western sides. The main portico on the northern side was badly cracked and had to be demolished. The first floor of the building was badly damaged. In the eastern wing part of the north-eastern corner crashed and fell towards the east and the roofs of both the ground and first floors collapsed bringing down with them one of the east-west walls; portion of the roof in the central portion of the first floor collapsed; the east-west walls showed evidence of horizontal shear. The jack-arched roofs of the western wing were badly cracked in an east-west direction. Both verandahs on the north and south collapsed and fell outwards, damaging the east-west walls. The ground floor of the building was also severely affected. The Town Hall is a one-storey *pucca* building aligned in the direction E 10° S. The walls were cracked and portion of the roof on the western side was heavily damaged and had to be dismantled. Direction of movement in this building was along its short axis (*i.e.*, north-south). The main hospital building was so damaged that it was dismantled, and some of the wards were almost equally affected. Several fissures traversed the compound. At the District Jail a portion of the east-west boundary wall, 15 feet high, on the north, collapsed and fell south and over three-fourths of the east-west wall on the south collapsed and fell north. Both the north-south walls showed numerous vertical cracks. Cracks appeared in most of the buildings, the north-south walls being affected more than the east-west. Some of the cracks were several inches wide, and extended from the ground. The entire upper storey of a two-storey *pucca* building which belonged to the late Mr. Aditya Ch. Bose collapsed. Both the east-west walls fell for the most part towards south. The *kutcha-pucca* house of Mr. Monoranjan Sinha, Deputy Magistrate, which has a light thatched roof, was affected only by minor cracks, mainly in the north-south walls. The first floor of the two-storey house belonging to Babu Manick Chand, late Treasurer, Government Treasury, in Bengali tola totally collapsed. On the ground floor the north-south walls were heavily cracked, the east-west walls only slightly. In the quarters of Mr. Mohammed Sadiq, Deputy Magistrate, a one-storey *kutcha-pucca* building aligned N. 10°W., the north-south walls were cracked by shaking while the east-west walls were fractured by slight sinking at the eastern and western ends of the

house. Numerous sand vents occupied the compound and the well was choked with sand. In the bazaar almost all the buildings either tumbled down or were badly affected. The damage was aggravated by heavy sanding and fissuring. In places the road level was raised. The direction of movement from fall of buildings appeared to be mainly north-south. The railway station buildings were a little damaged by cracks. Sand was ejected on both sides of the platform and in patches in the vicinity. The east-west walls of a goods shed, aligned north-south, collapsed. The east-west walls of several houses close to the station collapsed. There were definite indications of north-south movement in the vicinity of the railway station.

Sakri (26° 12′ : 86° 06′).—This small village, 12 miles E. N. E. of Darbhanga, is just outside of isoseismal X, but the ravages of the earthquake were not so impressive as at Laheria Serai or Darbhanga. There are here no two-storey heavy buildings and very few of the one-storey *pucca* and *kutcha-pucca* houses collapsed in the sense of tumbling to the ground. However, cracking of these houses was severe in comparison with similar buildings elsewhere within isoseismal IX. Sanding at Sakri was noticeably absent although sand vents were seen in profusion on both sides of the road to Darbhanga outside of four miles from Sakri. Sand vents were noticed occasionally up to three miles south of Sakri on the road to Bahera but beyond that such phenomena were rare. Within this stretch of the road, emission of sand was at its maximum near the village of Harpur. Here the sand extended over a distance of several hundred yards covering the land to a depth of a foot and half in places. The roads were slightly damaged here and there partly by subsidence. The masonry bridge at Sakri was damaged. Heavy outburst of sand was noticed a couple of miles east of Sakri on both sides of the railway and the railway embankment subsided unevenly. Beyond half-a-mile north of Sakri and up to Lohat, emission of a fine grey sand was frequent, attaining in places a depth of nearly two feet. Some of the damaged buildings at Sakri are described below :

In the one-storey *pucca* built Dak Bungalow, aligned north-south, the lower part of the nothern walls cracked as a result of north-south ground fissures. The eastern and western walls were unaffected. The floor of the eastern verandah moved one inch to the east. Sand vents were associated with north-westerly fissures to the west of the bungalow. The chowkidar of the bungalow felt the movement coming from the west and heard a roaring noise like that of a motor car. He was unable to stand during the movement. An unfinished building close by also showed similar evidence of movement in an east-west direction ; the central portion of the western verandah collapsed and all the pillars fell towards the west. The village school, a *kutcha-pucca* structure, was little damaged. In Abdul Wadood's house, an old one-storey *kutcha-pucca* building built around a central courtyard, the north-south walls were cracked, and the roof of a room in the north-western corner of the house collapsed. Portions of the east-west parapet at one side of the building fell either to the north or south. The village mosque was not damaged except for a few fine cracks on the central dome. Of the four turrets that on the south-western corner fell towards S. 60° W., and the one at the south-eastern corner fell towards the north-west. Fine cracks were present in the paved court of the mosque compound. Most people agreed that the shock came from a north-westerly direction. The

minarets of another mosque on the Sakri-Jhanjharpur Road fell but the mosque itself was not damaged.

Lohat (26° 17′ : 86° 08′).—The approach to Lohat was marked by fissures and large sand vents. A large number of houses were cracked badly but very few of them collapsed. Some of the bungalows of the Indian employees of the Lohat Sugar Factory were damaged by fissures. At the factory the east-west boundary walls fell both north and south but the north-south walls were standing. The steel chimney was not damaged. The east-west walls of the manager's office were more severely cracked than the north-south. In one room a north-south wall was inclined eastwards and was separated from the roof by about two inches. The southern wall in this room was heavily cracked. The eastern portion of this building sank about three inches and the floor in the same room was cracked in a north-south direction parallel to the joints of the patent stone slabs. Bottles on a rack fixed to the western wall in the laboratory fell westwards but none of those on a similar rack fixed to the eastern wall fell. Large glass jars in this room fell southwards. The floor of the power house was covered, to a depth of one foot, with fine grey sand, which emerged from sand vents on the north-western corner of the house. A crane supported on two joists running north-south rolled from north to south at the commencement of the shock and remained stationary at the extreme southern end. The floor of the mill house was tilted to the north-west, subsiding nine inches at the north-west end. The floor of the power house sank slightly. The eastern and the western walls of the store room (N. 20°E.—S. 20°W.) also were more cracked than the other walls. Portion of the floor sank and was covered with sand about two feet deep. The east-west walls of the godown shed collapsed and fell both north and south. Inside the factory a large syrup tank (10 feet by 6 feet), made of steel, rotated in an anticlockwise direction and the western corner shifted southwards from its former position by 30 inches. In the factory compound the water level rose ; a trial pit was dug in the compound soon after the earthquake and water was encountered at a depth of 4½ feet and it stood at this level for several days. Later, however, the water level subsided. The normal water level for that time of the year is at about six feet below the surface.

Pandaul (26° 15′ : 86° 04′).—Sand vents and ejected sand were noticed in the cultivated fields on both sides of the road from Darbhanga to Pandaul. The masonry bridge at 2½ mile from Darbhanga was damaged. The village itself also showed signs of a severe shaking. The bungalow of the Manager of the Raj Estate suffered badly. The southern portion sank and leaned towards the south and the verandah on the eastern side leaned outwards. The western portion of the house also subsided. The roof of the central hall collapsed. The Manager reported that he felt the shock coming from the north and heard a heavy rumbling noise. The shock lasted from two to three minutes. The strike of fissures on the eastern side of the compound was E. S. E.—W. N. W.

Pusa (25° 59′ : 85° 40′).—This was the site of the Government of India, Imperial Agricultural College, with research laboratories, experimental cultivation farm and cattle-breeding farm, and is situated on the southern bank of the Burhi Gandak, near the western boundary of Darbhanga district. The estate covers an area of about 1,300 acres, of which some 800 acres were cultivated, the remainder being occupied by roads, avenues, house sites, etc.

The comparative isolation of the place and the damage sustained by the buildings led the Government of India to abandon the site after the earthquake and to

remove the institution to within easy reach of New Delhi. The grounds of the Pusa Estate were traversed by large fissures varying in direction from W. N. W.—E. S. E. to N. W.—S. E. The fissures were not very deep and the breadth varied from a few inches to one foot. At one or two places the directions was N. E.—S. W. The magnificent two-storey Institute building was destroyed by a set of parallel fissures running the length of the building. Its site, close to the southern bank of the Burhi Gandak, was unfortunate for this type of heavy structure. This building was perhaps the most costly single Government structure which was damaged by the earthquake. Cracks in the walls were more prominent on the northern or river side of the building. A number of bungalows within the estate were badly damaged ; those traversed by a line of fissures subsided, gaping cracks appeared in the walls and the floors cracked. Several buildings escaped with minor damage, especially on the southern side of the estate away from the river. Sand and water welled up quietly from fissures or wells at Pusa and not in the form of fountains as elsewhere. A description of the damage done to the more important structures is given :

The massive two-storey Institute building (including Phipp's laboratory), aligned in a direction E. 20°S., lies south of and within a stone's throw of the Burhi Gandak. The main building has two wings projecting south at right angles to its long axis, at the eastern and western ends. A huge central dome, above the main staircase, is supported on pillars, arches and walls of sandstone, and is surrounded by four smaller domes. Two solid brick towers surmounted by domes occupy the centre of the terraces of the wings on the eastern and western sides. The entire building was dislocated by five parallel ground fissures which extended from the ground to the first floor, from one end of the building to the other, although they were more prominent on the eastern side and were more in evidence on the river (northern) side of the eastern wing and they diminished both southwards and westwards. As a consequence of these cracks, some of which were several inches wide, several pillars of the eastern varandah were inclined either towards the north or south. Some portions of the south-western corner of the southern verandah of the eastern wing fell towards the west and some towards the south, and the parapet together with several pillars was tilted towards the west. One of the longitudinal cracks displaced the northern portion of the eastern wing from near its junction with the main wing and as a result portion of the same wing sank about eight inches. The eastern wing was further damaged by a transverse crack which caused the south-western corner to tumble southwards. Portions of the roof both on the north-western and south-western corners of the eastern wing also collapsed. The cement floors of the whole building and the marble floor of the central entrance hall were cracked, as also, of course, the partition walls. The north-western and south-western portions of the roof of the west wing collapsed, but the partition (north-south) walls were not so severely cracked as in the east wing. In this wing also a narrow transverse crack caused collapse of the south-eastern corner. Portion of the south-western corner of the southern verandah of the western wing tumbled down part towards the west and part towards the east. Pillars on the balcony in this wing were tilted towards the west. The main (E. S. E.—W. N. W.) walls of the main building were little damaged and none of the many glass windows were cracked or damaged by the movement. Naturally the cracks followed planes of weakness, such as the junction of the slabs of patent stone forming the floor and also the sides or tops of the arches and

doorways. Portions of the concrete floor on the northern side of the eastern and the western wings were upheaved and the floors gave way near the joint planes through which some fine sand issued.

In the rooms of the first floor many objects fell, the majority towards the north or south, but the direction may have been influenced by the manner in which the building was opened up by the east-west fissures. A few objects fell towards the west. The partition walls on the first floor, particularly in the eastern wing, were badly affected by gaping cracks. One of the partition walls in the western end of the building was displaced laterally, to the east at its north end and to the west at its south end.

In general the roof of the main building was arched along an E. S. E.—W. N. W. axis. The old cemented cracks in the roof were opened up along the long axis but a few transverse cracks were also developed. In addition there were three longitudinal cracks on the roof.

The compound of the Power House was covered with sand about a foot deep in places. Sand and water flowed from a well 30 feet deep and the well itself became choked with sand. The well was re-excavated and at the time of visit no water had been obtained down to a depth of 45 feet. The chimney at the Gas House was twisted clockwise to the extent of 15° and a 15 inch square masonry pillar 99 inches high broke off three inches from the base and fell in a N. N. E. direction. Using West's formula this gave an acceleration of 1,500 mm. per second per second. Firebricks from a pile fell due north.

The Director's (Dr. Macrae) bungalow escaped with minor damage to the walls. A wash basin full of water, standing against the northern wall of the bath room, splashed water in a direction S. 10°W. A tank spilled water both to the north and south. A fan in Dr. Macrae's bed room oscillated north and south.

No. 9 bungalow was the worst affected house on the estate. It was severely damaged by a large fissure about 200 yards long and two to three feet wide, and the strike of which was E. N. E.—W. S. W. Mr. Joseph's bungalow was badly damaged. The north-west wall on the western side of the bungalow fell towards the west and the east-west wall towards the north. In the dining room two bottles of sauce were bodily thrown to a distance of four feet in a westerly direction from the middle of the dining table. A crack over half a mile in length passed through the Tara (sick) animal shed and on to the polo ground, the ground subsiding one foot to the south.

During the shock the calves stampeded and ran towards the cattle shed. The milch cattle were let loose and were running excitedly in all directions. Next morning there was a drop in the yield of milk. Other cattle showed signs of excitement. Several dogs were rushing about.

Bahera (26° 05′ : 86° 07′).—This village is situated about 20 miles south-east of Darbhanga. The damage to buildings here was not so great as at Darbhanga—mainly because it possessed no heavy structures—but it has been included within isoseismal IX. Almost all the houses here were cracked, even though the roofs were mostly light. Several *pucca* houses in the bazaar collapsed, killing two persons. Emission of sand was not extensive within the village ; few wells were choked but others were free. The police Sub-Inspector reported that the shock came from a N. N. W. direction at about 14.10 hours. The police station walls were cracked above doors and windows. At the Dak bungalow all the walls of

the rooms were cracked but the east-west walls suffered the worst, and parts of the arches of the western verandah came down. The direction of movement appeared to be east-west. The chowkidar said that the movement came from a north-westerly direction. The north-south walls of a one-storey bungalow, south-west of the Dak bungalow, were more heavily cracked than the east-west walls. At the hospital, a one-storey *kutcha-pucca* building, the east-west walls were cracked more heavily than the north-south. The direction of movement in this building appears to have been east-west. Assistant Surgeon H. B. Ghosh reported that the hospital pendulum clock, which was hung on the western wall, stopped at 14.14 hours. A wooden bracket fixed on an eastern wall fell towards the west. In the compounding room all the bottles in the almirahs standing against the western wall fell towards the east. The Assistant Surgeon heard a rumbling sound coming from the north-west but saw the building swaying in an east-west direction. In the Assistant Surgeon's quarters it was the east-west walls that were affected the most. Cracking of the north-south walls was entirely due to structural weakness. At the Benipur Indigo Factory, about a mile and a half east of Bahera, the masonry chimney swayed in a north-south direction and portions fell both to the north and south. The manager's bungalow was slightly damaged and the chimney fell towards the west. According to the manager's wife the shock commenced at 14.10 hours.

Berhampur (26° 12′ : 86° 06′).—In this village to the south of Sakri, the walls of a few *kutcha-pucca* and *kutcha* buildings fell, but a number of one-storey *kutcha-pucca* buildings escaped damage. Some fissures and sand vents were noticed in the centre of the village.

Daitalaha (26° 15′ : 86° 04′).—The bridge on the Kamla river near this village collapsed. The road and the surrounding cultivated land, especially close to the village, were heavily damaged by fissures and sand vents. North of Daitalaha the sand deposits were grey and cream coloured and coarse in texture. Near the Kamla the fissures were parallel to the river bank. Some mud huts were badly damaged.

Jaynagar (26° 35′ : 86° 09′).—This village was badly damaged, and it is just outside isoseismal X and at the edge of the Slump Belt. Some 100 people were killed. Buildings in the bazaar area sank and the floors were cracked permitting sand to come through the floors. Sand was one foot deep in the dispensary compound. The dispensary and the doctor's quarters slumped into the ground. Wells were filled with sand. Railway lines were badly twisted and buckled and some of the bridges collapsed. Additional cracks developed in buildings by the later shock on the 25th of January 1934.

Simra (26° 17′ : 86° 18′).—Heavy ejectment of sand from vents was noticed on both sides of the road close to this village near Jhanjharpur.

Phulparas (26°21′ : 86°29′).—This small village in Madhubani subdivision lies to the east of Madhubani. The mud huts with lightly thatched roofs were undamaged, but half-a-dozen *kutcha-pucca* buildings were badly damaged. No fissures or sand vents occurred in the village, although sanding was abundant a few miles to the north and south. Some of the wells in the village were choked with sand. Most of the villagers agreed that the shock came from a north to N.N.W. direction sometime between 14·10-14·15 hours. A rumbling noise, like that of a motor car, was heard during the shock.

The Dak bungalow sustained slight cracks. The north-south walls of the Spirit Warehouse, a *kutcha-pucca* building, were badly cracked, but the east-west walls were not much affected. The office building to the east of the warehouse collapsed completely. The Registry Office, a one-storey *kutcha-pucca* building, partially collapsed. The eastern verandah was the first to collapse. The greater part of the Sub-Registrar's quarters, a one-storey *pucca* building, was razed to the ground, only a portion of the room at the south-eastern corner of the house was left standing. In the northern compound narrow fissures ran east-west, about an inch wide. The south-eastern portion of Ramjiwan Dube's one-storey *kutcha-pucca* house collapsed. The western wall was leaning towards the east and the south-western corner fell. Portion of the south-eastern corner of the eastern wall also collapsed. A two-storey *kutcha-pucca* building near by collapsed altogether.

Pipra Ghat.—Ejectment of sand was moderate here.

Chanauraganj (26° 17′ : 86° 19′).—A large number of huts in this village were damaged and about half-a-dozen totally collapsed. The crops in the surrounding lowlands were damaged by emission of sand from vents.

Sarso Pahi (26° 15′ : 86° 09′). Collapse was confined mainly to a few old *kutcha-pucca* buildings. Most of the newly-built buildings showed little sign of damage.

Bhagalpur district.

Supaul (26° 06′ : 86° 36′).—This town is the headquarters of the subdivision of the same name in Bhagalpur district. It is on the northern edge of the Slump Belt but the damage was by no means as severe as in towns to the west. Both subsidence and shaking were responsible for the destruction of buildings in Supaul. Government buildings were the most severely affected, but the majority of these could be repaired. In the bazaar several *kutcha-pucca* houses partly collapsed and all were badly cracked. Ground fissures caused fracturing of the walls of some buildings. An abandoned brick sugar mill two miles east of the town partially collapsed; the top of the chimney (free to move equally in any direction) fell to the west. The dominating ground tremors were definitely east and west. Roads both in the town and subdivision were fissured. Embankments sank and sand vents were formed, more particularly along the District Board road south of Supaul.

Emission of sand was not heavy in the town. The water level in wells rose slightly after the earthquake. Although most people were of the opinion that the shock acted in a N. W.—S. E. direction, the direction of fall of objects was mostly towards the west. At the Railway Station fissures ran north-south along the platform, and the station building was cracked over the arches.

The eastern verandah of the S. D. O.'s quarters, a one-storey *pucca* building, collapsed completely and the bungalow was badly fractured. The Subdivisional Officer, who came out of the court at the commencement of the shock, remarked that the ground first moved up and down and this was followed by ripples moving from north-west to south-east and finally by a violent shaking in all directions. The walls and floors of the Criminal Court, a one-storey *pucca* building, were cracked and there was unequal subsidence. The sinking continued for many

days after the earthquake, doors which could be opened at first became jammed later. Verandah pillars leaned outwards. The Bar Library was completely ruined. The Registration Office, a one-storey *pucca* building, sank and was tilted towards the east and the long east-west walls were badly cracked. Several ground cracks running in a general N. E.—S. W. direction traversed the compound south of the building. One of the worst affected buildings in Supaul was Williams H. E. School, a one-storey building partly *pucca* and partly *kutcha-pucca* and through which ground cracks passed from east to west. The walls, floors and the roofs of the side rooms were split open. There were about ten such cracks varying in width from ¼-inch to as much as three inches. In general the east-west walls were less damaged than the north-south. Some of the cracks affected the well in the western compound. It was stated that sand at first gushed out to a height of four or five feet and was followed by a column of water of the same height. The sand emerged just as the main shock diminished and the water almost at the end of the whole shock. Fissures in the compound ran E. N. E.—W. N. W. and N. E.—S. W., the ground partly subsiding. The Headmaster of the school thought that the shock commenced at 14·16 hours, from the north-west, and was preceded by a loud rumbling noise and tremors. As he was standing in the compound he noticed distinct surface waves the length of which, he thought, was between 25-30 inches from crest to crest. The movement was lateral as well as vertical and he had difficulty in standing. The church walls were cracked by east-west ground fissures and the building sank a little on the northern side. The western wall leaned towards the west and the eastern towards the east. The Dak bungalow was affected by a few slight cracks. At the Co-operative Bank, a one-storey *pucca* structure built in 1925, all the walls had horizontal as well as inclined cracks. The building sank near the centre and was tilted towards the north. Fissures ¼ to ½-inch wide and striking N. 10°E. were present both on the eastern and the western sides of the building, but no sand was ejected here although sand emerged from fissures further east. The walls of the Public Library were cracked and the floors raised in places. The Welsh Mission Hospital, a one-storey *pucca* building, was somewhat damaged by cracks on the walls. An abandoned brick sugar mill near Supaul collapsed. Several walls, one 7 feet 6 inches high and 14 inches wide, collapsed to the east, but others fell to the west. Most of the east-west walls were standing. The tall, heavy brick chimney shook in an east-west direction, and the top portion fell to the west and the northern and southern sides were cracked. The river bank in the vicinity was badly fissured. In the bazaar some walls fell, some west, some north.

At No. 14 railway bridge, north of Supaul, a girder structure of three spans, aligned north-south, all the piers were cracked and were tilted towards the west. The fixed south end of each girder pulled the bed plates northwards as much as four inches to six inches, and in addition one was shifted ½-inch to the west. The girders and the rails were bent sideways towards the west on account of the tilt of the piers. The upper portion of the northern abutment pillar separated from the lower half and was heaved about one foot towards the north.

Nauhatta (26° 00′ : 86° 05′).—This village, about seven miles W. N. W. of Panchgachia R. S., was very badly damaged. Out of the 15-20 *pucca* houses that the village possessed, four or five collapsed. The ground was fissured and much sand was ejected. Murli and Lirajpur villages were similarly affected.

Panchgachia (26° 00′ : 86° 06′).—This village, in thana Bangaon, is situated on the District Board road from Bhaptiahi to Bulhi. It is about two miles west of the railway station and about 18 miles west of Madhipura. A large number of *pucca* houses, all very old buildings and a number of them with two- and three-storeys, collapsed. The new *pucca* buildings were badly cracked but did not collapse. Some large *pucca* bungalows collapsed, although not to the ground. The number of collapsed houses was about 40-50. About 25 per cent. of the land was covered rather thinly by sand. The ground was fissured and sand and water issued from the vents.

The District Board road between Panchgachia and Supaul was badly affected. Sand vents and fissures in profusion were a common feature of the country side from Panchgachia to four miles beyond. *Kutcha-pucca* houses in the villages on both sides of the road collapsed. This portion of the country was very reminiscent of Sitamarhi. The central piles of the bridge four miles north of Panchgachia, leaned both east and west, two central spans collapsed. The western span leaned westward and the eastern one eastwards, but the piles on either bank remained vertical. A temple alongside collapsed completely.

Madhipura (25° 56′ : 86° 48′). This village was the headquarters of the subdivision of the same name in the Bhagalpur district, but has been abandoned since the earthquake as a result of encroachment by the Parwan river, a branch of the Kosi, which flowed past the eastern side of the town site.

This township was within the Slump Belt. Owing to the lightness and small size of the buildings the damage was much less than otherwise might have taken place. The most severely damaged building was the hospital, a large modern structure which subsided and opened out in all directions and was completely wrecked. Other public buildings subsided a few inches and were cracked, but most were habitable. There were numerous ground fissures, striking principally N. N. E.—S. S. W., and one such fissure traversed the length of the town. The small bazaar, built mainly of bamboo and grass huts, remained undamaged. Four *pucca* and several *kutcha-pucca* houses collapsed. The severity of the shock in this small town was demonstrated by the fall of three trees with large roots; two fell north, one south.

The *bund* surrounding the town subsided and cracked in many places. East of the town the river breached the *bund* and eroded westward behind the original *bund* alignment.

Portions of the Jail walls fell down. The Warders' quarters collapsed. The Thana, a *kutcha* building, was badly cracked and portions of the south-western corner collapsed. The Munsif's Court was cracked and badly damaged, and the floor cracked and sank. The Criminal Court was completely ruined; the roof was badly cracked and part of it fell; the floors and the walls were cracked and sank. The direction of the cracks on the floors was north-south. The Local Board Office was cracked and it subsided, but the damage was repairable. The Dak bungalow was cracked and it sank about two inches but the damage was repairable. The S. D. O.'s bungalow, a fairly new and well-built brick building, was slightly damaged by north-south cracks. The Subdivisional Officer remarked that the shock came first from the north-west and then from the west.

Nirmali (26° 18′ : 86° 36′).—This village, about seven miles E. S. E. of Phulparas, was badly damaged. The station buildings and newly built houses were slightly cracked but other *pucca* and *kutcha-pucca* buildings collapsed.

Bhaptiahi (26° 18′ : 86° 42′).—Here, as at Nirmali from which it is situated about ten miles to the east, *pucca* and *kutcha-pucca* buildings were badly fractured. The chimney of a mill fell towards the east. Two single-storey *kutcha-pucca* buildings, used as rice mills, were badly fractured.

Kunali or *Khandauli* (26° 27′ : 86° 49′). This village is within a short distance of the Nepal boundary. There was a partial collapse of almost all the *pucca* buildings and only two, which were rather new, escaped and these were cracked. The Dak bungalow, a *kutcha-pucca* structure, collapsed completely.

Dagmara (26° 25′ : 86° 45′).—This village is about four miles south of Kunali, all the buildings were badly fractured.

Bhimnagar (26° 31′ : 86° 57′).—This old village, the site of which was about 15 miles north of Pratapganj and within a short distance of the Nepal frontier, is no longer in existence and is now replaced by Raniganj. Here all the houses are of *tatti* (bamboo wattle), hence no damage was visible. There were a few ground fissures, which were dependent on the prevalent depressions.

Pratapganj (26° 18′ : 86° 58′).—*Pucca* buildings were cracked but not very seriously damaged in this village, which is about 28 miles to the north-east of Supaul. Some of the buildings sank slightly. The Thana, the Dak bungalow and the Hospital were all cracked, but not seriously.

Raghopur (26° 17′ 86° 51′).—At this village, about seven miles to the west of Pratapganj, the Dak bungalow partially collapsed. A large old bungalow about two miles from the village almost completely collapsed.

Pipra (26° 10′ : 86 °48′).—Situated about 13 miles E. N. E. of Supaul, *pucca, kutcha-pucca* and mud houses in this small village collapsed or were badly fractured. The Hospital, of *pucca* brick construction, partly collapsed. Fissures and sand vents dotted the country side.

Murliganj (25° 54′ : 87° 00′).—This village is about 13 miles to the east of Madhipura, and is the terminus of the branch of the E. B. Railway from Purnea. Murliganj is situated on the west bank of the river Daus which is now virtually the main Kosi.

Most of the houses in this part of Bhagalpur district consist either of bamboo and mud with corrugated galvanised sheet-iron roofs, or they are thatched grass huts which do not show earthquake damage easily. All the bamboo and mud huts were cracked and the railway station was also cracked. Some *kutcha-pucca* houses at Murliganj were badly cracked. Between Janakinagar and Murliganj there were some sand vents and cracks. The village itself comes within the main Slump Belt.

Conditions were also similar at Behariganj, a village about 12 miles due south of Murliganj, and between these two villages there were many fissures. Innumerable cracks and fissures were present along river banks, which were in places faulted into the river.

Purnea district.

Purnea (25° 48′ : 87° 30′).—This town, the headquarters of the district of the same name, is situated along the Saura river. The population in 1931 was 15,474. The town is long and straggling, and contains five distinct localities, *viz.*, the town proper, the civil station, Khazanchi Hat, Bhatta and Madhubani. The old town is situated on the left bank of the river and is connected with the civil station by

a small bridge. The town stands on sandy alluvium which is presumably 'older alluvium'. This sandy country is flat and low near Purnea, but further north it rises and undulates considerably and pebbles are associated which gradually increase in size as the hills to the north are approached. The newer alluvium lies south of Purnea, but the junction between the two is obscure.

Purnea is undoubtedly the extreme eastern limit of the most serious damage and is at the east end of the Slump Belt. Although government and other structures in Purnea did not actually collapse, the damage on close inspection was almost as spectacular as at Monghyr. The principal destructive movements appear to have been east-west.

There were but few cases of houses collapsing, and the shattered buildings, with cracks and gaping fissures up to one foot in width, were, in almost all cases standing erect. It was because of this that the toll of life was negligible—only two lives were lost—in comparison with the destruction of property. The very breaking up of the foundations by subsidence prevented the collapse of the buildings. About 50 per cent. of the *pucca* buildings were so completely ruined as to require re-building and 90 per cent. were so badly fractured that they were rendered uninhabitable and had to be extensively repaired. The most frequently quoted example of subsidence was the east wall of Darbhanga house which sank between three and four feet. The Civil Court, the largest building in the town was cut across by an east-west fissure along which subsidence was as much as two feet.

Many private houses, especially heavy two-storey structures, were destroyed. It was interesting to note that between adjacent and similar houses one was often destroyed and the other unscathed; the damage depended on the amount of subsidence, which was governed by fissures and adjacent sand vents.

This behaviour of ruined houses at Purnea is a contrast to those in Monghyr, where entire streets were levelled to the ground and formed heaps of debris. It was obvious in Purnea that the structures were much too heavy for the sand foundation on which they were built. In many cases the heavy buildings were themselves responsible for fissuring the neighbouring ground.

In the old town, to the west of the civil lines, the damage was slight. This was not due to any apparent difference in the alluvial ground below the foundations, although sand vents were admittedly absent, but to the much lighter nature of the structures. The part of the town on the northern side of the river was singularly undamaged, except for very *kutcha* buildings which collapsed. Most of the shops in this part of the town are of brick construction and were undamaged. The house of the Raja of Purnea on this side was only slightly cracked.

The steel piles of a bridge between the civil lines and the railway station were broken, and the piles were shifted slightly by a foot or so. The banks of the river appeared to have closed in a little. A brick arch bridge between the civil lines and the old town was also fractured; one of its piers was slightly out of line. One of the most extraordinary examples of distortion to a screw-pile bridge took place at the Kali Kosi river one mile from Champanagar, north-west of Purnea. The centre piles moved south, downstream, as much as seven feet eight inches, but remained more or less vertical. The bridge took on a sharp bend downstream.

The civil lines occupy a large area of country; buildings are widely scattered. The ground was traversed by innumerable fissures, some aligned east-west, the majority north-south. Sand was ejected from many of the fissures and from other

vents—in some cases large holes with tunnels were left after the sand was ejected. The fissures followed the configuration of the ground, such as *nalas*, embankments, etc., and there was a little horizontal and vertical displacement along some of them. The north-south fissures appeared to be longer than the east-west; one or two could be traced for half a mile whilst the east-west set were not more than a couple of hundred yards in length. Many of the fissures were quite wide and gaping. Along one of the roads there was a hole five feet wide and twelve feet deep with two tunnels on either sides. Another was five to six feet wide and filled with fine grey sand. In places the ground was honeycombed with fissures.

In the immediate neighbourhood of Purnea the surface of the ground was thrown into long shallow undulations. Accompanying the formation of the ground fissures, sand and water spouted like fountains from newly opened vents as well as from wells. Wells, tanks and depressions were infilled by sand from below in the case of wells to an average of 15 feet above their original bottoms. As most of the wells and many tanks in Purnea were infilled there was a scarcity of water for a time. On re-excavating the wells the water level was found to have fluctuated.

Roads became undulating owing to subsidence but this type of damage died out rapidly to the east, south and north of Purnea. River banks closed in, in some cases as much as seven feet, but averaging five feet—reducing the waterways a total, therefore, of ten feet; this was well indicated at the District Board road crossings. In the country north and west of Purnea the railway lines were buckled and twisted and the violence of the movement was sufficient to throw the rails away from the track; lateral shifting of telegraph poles and bridge piers, occurred, in one case they were moved seven feet out of alignment.

In contrast with the general disturbance of the surface of the country trees were noticeably immune from damage all over North Bihar. Near Purnea only two trees were uprooted and thrown on their sides.

The various phenomena may be accounted for, to some extent, by the nature of the sub-stratum on which the town of Purnea is built. This is a thick bed of extremely fine, soft sand, a deposit of the old and now deserted bed of the Kosi.

Conflicting reports give the time of incidence of the shock between 14·15 and 14·36 hours (I. S. T.), and it lasted for over 180 seconds. The noise accompanying the preliminary tremors was variously described as a loud rumbling, like thunder, or was compared with the noise of a motor car or aeroplane. Some people heard no noise. The direction of the first vibrations was given by a careful observer as roughly N.W.—S.E., followed by movements in another direction, and later by distinct vertical movements of the ground. The fall of objects, however, did not seem to favour any particular direction.

Some of the more important buildings may be described:

The two central *ijlas* of the Collectorate were badly fractured, but the northern and the southern portions of the buildings were not so severely affected. The main portion of the Collectorate Record Room was severely affected, but the two rooms at the south and the southern verandah escaped with minor repairable damage. The large cracks in this building were due to subsidence. The central portion of the old Collectorate had a domed roof which was badly fractured so that this portion of the building had to be dismantled. The southern and the northern portions were also cracked. The Civil Court was shattered by an

east-west fracture which cut right across the southern part of the building, with a subsidence of as much as two feet on the south. The entire building was badly cracked and subsided as a whole by a few inches. Only the northern end of the building could be retained. The enclosure wall of the District Jail fell and prisoners escaped. The office buildings of the Jail Superintendent and the Jailor and the Warder's barracks sagged and were badly cracked. Only the northern portion of the prisoners' ward could be repaired, since the rest of the ward with domed roof was badly damaged. The central portion of the hospital building was severely fractured and had to be dismantled but the northern end and the southern portion could be repaired. Portions of the District Judge's residence had to be dismantled. The Police Superintendent's bungalow slumped and had to be demolished. Besides being badly fractured the Civil Surgeon's bungalow also sagged. The major portion of the Purnea Zilla School building was badly cracked and part sagged. A large portion of the building and of the hostel had to be demolished. The Circuit House was wrecked by large north-south cracks which were up to five inches in width. There were minor east-west cracks. The building sank six inches below the ground gutters. The main movement here was definitely east-west. The hospital building sank in the middle and was severely cracked. Most of the wide cracks were north-south, as a result of east-west movements. Two shocks were felt by the hospital staff; the first one lasted for 150 seconds and after an interval of thirty seconds there was a second and a severer shock for 90 seconds. It was during the second shock that fracturing of the buildings took place. The first shock was in a N. E.—S. W. direction and the second in an east-west direction. Dr. Mullick, however, felt an east-west movement during the first shock followed a second N. E.—S. W. shock. Fissures appeared with the second shock. At the Cemetery large east-west fissures were formed in the ground but curiously, none passed through a grave! The walls were broken and fell, the north wall subsided in part down to ground level in a sand filled fissure. Much sand was ejected. Some of the monuments sank, but no monuments actually overturned. An adjacent road was riddled with fissures. Darbhanga House was completely ruined; the principal fractures were in the east-west walls and the eastern wall sank about four feet. Fissures with ejected sand were formed in the adjacent ground near Darbhanga House; these fissures were aligned north-south and one of them ran below the eastern wall of the house causing its subsidence. The roof collapsed inside the building. The Raja of Barailli's house was completely ruined by severe cracks and the floor was broken up; the main cracks were north-south. The Church was completely ruined by cracks and the building subsided. The Indian Club, a newly erected structure, was completely fractured; all the walls sank and the eastern and the western ends were tilted; the concrete floor was raised and was badly fractured. The building was surrounded by sand fissures. In the bazaar most of the houses were built of bamboo and were unaffected.

Forbesganj (26° 18′ : 87° 18′).—This village is situated 42 miles by rail north-west of Purnea. Its population in 1931 was 5,939. Going north from Purnea much fissuring and a few sand vents were noticeable for the first 10 miles, then the country showed little disturbance and only rare fissures up to Araria. North of Araria, and especially approaching Forbesganj, road conditions became bad owing to the presence of fissures and sand vents.

At Forbesganj several brick buildings collapsed. Most of the buildings at Forbesganj are constructed of galvanised sheet iron so that the effects of the

shaking were not marked. The wall cracks gave no information of the direction of the ground waves. The station building was practically undamaged. The bridge half a mile west of the station collapsed. Another girder bridge north of Bhatiahi station, about two miles south of Jogbani, had to be supported on sleeper piers until the damaged piers were repaired.

The fissures around Forbesganj were rather constant in direction—either north-west or north-north-west. As the country is flat, or gently rolling, it cannot be said that the directions of the fissures were governed by any particular surface depressions. It is quite probable that here in Purnea district they were governed by the direction of the surface waves.

Jogbani (26° 24′ : 87° 18′).—This tiny village at the extreme north of the Purnea district and about seven miles due north of Forbesganj is the terminus of the E. B. Railway. There were no fissures and little ejected sand. No wells were choked up. Houses were badly damaged, however, and this fact justifies the inclusion of Jogbani in isoseismal IX. Brick houses either partly or entirely collapsed. The station building as well as the staff quarters collapsed.

Raniganj (26° 05′ : 87° 14′).—On the road from Champanagar to Raniganj, a village 30 miles north-west of Purnea, a few occasional fissures from which some sand was ejected, were noticed. A few small cracks occurred in the village buildings and damage was slight.

Champanagar (25° 55′ : 87° 19′).—This village is about 15 miles N. W. of Purnea, and the surrounding country was considerably fissured and sand ejected. The Palace at Champanagar was cracked but not seriously. The porch on the eastern side was separated from the main building. The main cracks were aligned mostly north-south but one crack in a side building ran east-west. The movement was definitely east-west according to the people of the palace. The destruction of the screw pile bridge over the Kali Kosi river near Champanagar has already been described.

CHAPTER XVII.

ISOSEISMAL IX, SOUTH OF THE GANGES.

Patna district.

Patna (25° 42′ : 85° 12′).—The city of Patna, the capital of Bihar, includes its suburb, Bankipore, which is the headquarters of the Patna district and division. The city extends for about nine miles along the south bank of the Ganges and is about a mile and a half broad. The population of the city together with the new capital was 173,948 in 1931.

In spite of its historic past, the old city possesses few buildings of interest to the archæologist and like most of the towns in Northern India it is a long straggling city of brick houses or mud huts with tiled roofs. There are, of course, some fine modern buildings in the new city. Amongst buildings of historical interest are the fine mosque of Sher Shah (1540-45), built in 1626, and a temple erected by Ranjit Singh, "the lion of the Punjab" on the site where Govind Singh, the great Sikh Guru and founder of the Sikh military brotherhood, was born. The gola (granary) at Bankipore, is a curious beehive-shaped structure, 96 feet high, which was built in 1786 for the storage of grain as an insurance against famine. The old city is thickly congested with flimsy buildings and with the exception of the main street, which runs from east to west, is full of narrow, crooked and irregularly alleys, lined with insignificant houses. At the extreme west is the Patna College on the bank of the Ganges; close by are the Medical College and Hospital, and in the same neighbourhood are the Patna Oriental Library and the Bihar School of Engineering. The New Capital, which lies further west, includes Government House, the High Court, the Secretariat and other government buildings —all of recent construction.

Along the river front at Patna, the intensity of the shock was IX and buildings suffered severely. This was largely due to the fact that the oldest structures were situated in this part of the town. However, such fine modern buildings as the Nurses' quarters were damaged to an equal extent so that the age of buildings was not entirely the determining factor. Buildings in the bazaar collapsed and immediately after the shock the debris-strewn roads were impassable. Tall structures, particularly of *kutcha-pucca* construction, were the worst affected.

In the New City the damage (intensity VIII) was much less, but notwithstanding their recent construction the buildings did not escape lightly. At the Secretariat, roof copings were damaged; the clock in the tower stopped at 14·16 hours. The High Court was damaged to the extent of about half a lakh of rupees; cracks which appeared below the dome became worse for several weeks after the shock. The top floor of Government House was severely cracked and the majority of two-storey houses suffered similarly.

The principal movements took place in an east-west direction, but approaching the river north-south movements predominated. In the Patna Old Cemetery parts of several old monuments and pillars fell to the east or west, the majority to the east. Many observers spoke definitely of an east-west movement, buildings shaking bodily in that direction.

It is impossible to give a complete list of the damage in such a large city as Patna and only some of the most affected buildings are described:

Portion of the north porch of the Patna Junction station collapsed. The roof copings of the station building fell. The residence of the Superintending Engineer collapsed. The Government Press, situated on the bank of the Ganges and built in 1702, was heavily buttressed on the northern side. Formerly it was used as an opium factory, and formed part of the old Dutch factory. The main press room was heavily damaged and the southern portion collapsed. In the Composing room the pillars at the western end leaned towards the north. In the Deputy Superintendent's room the principal cracks were in the north-south walls, the arches on the east-west walls moved outwards. The majority of the beams in the terrace on the north were pulled out from the south, two fell east and west and the rest dropped perpendicularly. The weather vane on the top of the Round Tower fell in a N. N. E. direction. The ground floor of the Superintendent's house was of arched walls more than six feet thick and they were quite undamaged. Within the precincts of the press compound, there was a general tendency for the fractures close to the river to have arisen from north-south movement. At the southern side of the compound away from the river the principal cracks resulted from east-west movement. An adjacent house occupied by Mr. Hamid was completely ruined. The building was shaken in a north-south direction and there was little sign of any east-west movement. Mr. Williams' house was completely destroyed. Mr. Williams, who was standing outside facing the house, was of the opinion that the shock travelled from west to east and he felt an up and down movement towards the end. His house moved bodily in an east-west direction. The house occupied by Lt.-Col. Coutts was a semi-*pucca* building, and was fractured by both east-west and by north-south movements. The southern verandah fell to the south without any lateral movement of the rafters, which dropped perpendicularly. One cylindrical pillar fell due east against another pillar. Not one glass pane was broken in the whole building. The eastern side of the building was most severely damaged. The north wall opened northwards along old cracks. All the rafters on the western side were pulled out from east to west. The Nurses' Quarters, P. G. Hospital, is a recent building of excellent construction and situated close to the river. The walls on the southern side fell towards the south. The eastern side of the building was more severely damaged than the western side. The Patna College is a massive two-storey *pucca* building situated close to the river. The entire building was badly damaged. Portions of the roof on the first floor collapsed and the walls fell outwards both towards the north and the east. A cement ball, mounted on a vertical steel rod fixed to the roof coping on the southern side of the building was bent over due west; another on the western walls was also bent over in the same direction. These movements, therefore, definitely took place in an east-west direction and were due to a violent easterly jerk to the building from the west. At the Commissioner's house, a very old building made of sunburnt bricks, the porch on the east side tilted towards the east and portion of the eastern wall collapsed. On the northern side the walls showed a tendency to open towards the north. The porch of the Collector's house collapsed and some of the walls were cracked. At the Rev. P. John's bungalows the *nuria* tiled verandah on the western side of the bungalow collapsed. Mr. John noticed that the trees and the thatched

roof of the bungalow swayed north-south during the quake. The Regis Hotel was aligned in an east-west direction, and the damage was confined mainly to the eastern and western sides of the building. The roof copings on the north and the south fell outwards. The central portion of the building cracked but slightly. The buckling of the outside walls were responsible for most of the damage. The principal movement in this building was in a north-south direction.

Portion of the High Court collapsed. The portico at the entrance for judges and the portico at the entrance for advocates almost collapsed. The roof of the court rooms on the first floor cracked in several places and the Record rooms were also damaged. Most of the damage was to the roof coping. In the Registrar's room, aligned north-south, all the steel racks, for files, were aligned east-west facing north or south ; all the racks fell south. Here the movements appeared to have taken place in a north-south direction. Cracks appeared in the ground around the High Court. The northern end of the Assistant Registrar's house, near the High Court, subsided about four inches and leaned towards the north. The building was cracked across in an east-west direction. The top portion of the tower of the Secretariat building fell later and damaged the roof and coping. There were several cracks in the walls.

In addition to the buildings mentioned, and many *kutcha-pucca* structures, a large number of well-built *pucca* buildings were damaged to a greater or less extent. Amongst these are Government House, the Chief Justice's house, the late Sir Ali Imam's house in Fraser Road, the Allahabad Bank, the Co-operative Federation Office, the English Church in Bankipore, Mr. Justice Agarwala's house, the house of Mr. Justice Varma, the District Court buildings, the Imperial Bank, the house of Mr. Hosain Imam, a member of the Council of State, and the Science College buildings. The northern portico of the General Post Office was cracked and damaged. The *Statesman* reported that over 50 persons were killed, several hundreds were injured and over 4,000 houses in the town damaged or destroyed.

Barh (25° 29′ : 85° 43′).—This town, headquarters of Barh subdivision and with a population (1931) of 9,750, is on a northern salient of the Ganges. The intensity here was IX and the damage, on a smaller scale, could be compared with that along the river front at Patna, perhaps somewhat more intense. The Subdivisional Officer's court was almost completely razed to the ground. The S. D. O.'s bungalow partly collapsed, the remainder had to be condemned. All the other government buildings were severely damaged. The northern end of the bazaar within half a mile of the river, was the worst part affected, as almost every house was damaged to some extent, two-storey houses being, of course, the worst affected. The main bazaar road runs north-south and the buildings fell towards the west. The movements in Barh were mainly east-west, but again, as in Patna, a north-south movement asserted itself approaching the river. Thirteen lives were reported to have been lost. A few of the damaged buildings are described :

The S. D. O.'s Court and Sub-Registrar's office, aligned east-west, was almost completely razed to the ground, but windows and doors were left standing. The western verandah of the Court Offices and Treasury, aligned north-south, was badly damaged, the rafters were pulled out about two inches. The walls of the buildings cracked, especially above the door and window arches and were condemned. The eastern and the western wings cracked at the junction with the

main building. The S. D. O.'s house, of *pucca* brick and 20 years' old, was left standing, but was so severely damaged that it was condemned. The Munsif's Court, aligned E. 20°N., was severely cracked and had to be condemned. The verandah arches were reinforced with thin steel bars, but both the southern and eastern verandahs fell eastwards. The Barh General Hospital, a *pucca* structure, was severely cracked and was partially condemned. The Banarsi Ghat Mosque on the river bank is about one hundred years' old; a small minaret fell due west and came to rest at an angle of 45° from the horizontal between two cupolas. The southern side of the mosque collapsed. The roof copings at the railway station collapsed and the verandah was pulled away from the wall and collapsed; the walls were badly cracked.

Mokameh (25° 25′ : 85° 53′).—This town is on the south bank of the Ganges. In the bazaar fifty buildings collapsed, many were severely cracked and a large percentage had to be demolished. The town, on the whole, was not so badly shaken as Barh. At the railway station, an old building, most of the damage was caused by east-west movements. The station had to be completely demolished and rebuilt. The railway quarters were the worst affected and most of them rendered uninhabitable. All the walls opened outwards. In many cases there was a definite horizontal shear in an east-west direction. It was remarkable that the brick pillars supporting water tanks were not affected. At the Dak bungalow a *pucca* structure, the east-west movement of the roof cracked the walls badly. Effects of north-south movement were noticed on the north and the south sides, the centre rooms were the least affected. The eastern verandah was more damaged than the southern. The building was condemned. At the District Board School a *pucca* building, aligned E. 30°S., the eastern and western verandah pillars leaned outwards, tilting from the foundations. The northern wall showed a tendency to move outwards. In general, east-west movements appeared to dominate.

Monghyr district.

Jamalpur (25° 18′ : 86° 30′).—This town is the headquarters of the locomotive department of the East Indian Railway. The engineering workshops cover an area of nearly one hundred acres, over twenty acres of which are roofed over. The population in 1931 was 30,346.

The greatest damage was in the bazaar, north of the railway station, where many houses were razed to the ground and practically every house, excepting mud huts, was badly cracked. Here as elsewhere the *kutcha-pucca* structures suffered most. According to the *Statesman* 16 persons were killed. Just east of the station, houses, especially those with arched roofs, were razed to the ground. Others were wrecked and the remainder were more or less cracked. Tall two-storey buildings suffered most. Certain two-storey houses with iron sleeping shelters on the roofs fell away at the northern and southern ends and left the 'sleep-out' shelters suspended.

There was a rapid diminution in the intensity of the shock approaching the ridge east of the town and both the eastern and southern borders of the town were little disturbed, but the houses here were of quite recent construction. In the absence of structures on the ridge east of Jamalpur no impression could be gained of the differential effects of the movements there.

In the Railway Workshops the damage was confined to the brick structures and mainly to those built nearly 50 years ago. The greater part of the works was of steel frame construction which suffered no damage. Of the single storey brick buildings the long structures suffered most, more especially those aligned north-south, the northern and the southern ends collapsing. All structures with arched roofs, of which there were a large number in Jamalpur, were severely damaged. According to the *Statesman* 130 out of the 180 houses in the railway colony collapsed or were rendered uninhabitable. There were 17 deaths in the railway colony and 48 injured. In Jamalpur nearly everyone agreed that the first movements took place in an east-west direction. Some were of opinion that these movements changed to north-south while others felt a circular movement.

A brief account of some of the damaged buildings is given :

At the Stationery Office, 6 Loco Office road, the arched roof split right along the centre and opened up east-west. The southern end of the building collapsed and the north-south walls were badly cracked, but the east-west partition walls were left standing and were not heavily cracked. The outer walls parted from the partition walls in the interior of the rooms. At the Railway Institute the western wall of the baths fell *en masse* towards the west and the remainder was completely cracked. The baths were aligned east-west. The other Institute buildings were badly cracked, particularly in the east-west walls. According to the Secretary of the Institute, the movement first came from a little north of west, later the direction changed to north and south and the ground could actually be seen rolling in waves to a height of one foot. At the Railway Workshop, portion of the eastern wall of the machine shop fell towards the east. The lower part of the chimney house was badly cracked and the chimney leaned northwards. The steel chimneys vibrated in all directions. The brick foundation of one steel chimney had a vertical north-south crack. In the forge shop the western wall was pulled away from the roof and the western side of the roof dropped. The power house near the southern end of the shop was only slightly cracked. Only old brick structures were affected, the steel structures escaped. The northern and the southern ends of the watch and clock shop, the alignment of which was north-south, fell away.

The southern verandah of the Y. W. C. A. building collapsed and all the walls were badly fractured. The roof copings fell towards the north and the south. St. Mary's C. E. Church had a corrugated iron roof. The eastern and the western walls were not damaged but the southern wall collapsed. The belfry fell towards the east. The porch on the south end of St. Joseph's R. C. Church collapsed together with the top half of the southern wall. The eastern wall was badly fractured. The eastern and the western walls were pulled away from the northern and the southern walls. The top of the eastern and the western walls of the Union Church, aligned east-west fell. The church had a tiled roof supported on steel girders.

The railway station is aligned north-south. Portions of the roofs of the rooms on the eastern and the western platforms collapsed. The northern and the southern ends of the station building on the eastern platform fell outwards. Both of the arched roofs over the railway lines in the main station fell. All the east-west partition walls in the various rooms were badly cracked but the north-south walls were not much damaged. All the arches were opened up near the centre. The

Police Sergeant's house, a *pucca* building north of the station, was definitely rocked east-west; all walls aligned east-west had great diagonal cracks; the roof over the western wall had definitely moved outwards one inch towards the west; horizontal cracks appeared in the northern and the southern end walls.

Dharhara (25° 12′ : 86° 24′).—This small village, about seven miles south-west of Jamalpur by rail, was badly affected. The waiting room in the down platform of the railway station collapsed. On the up platform north and south walls were not much affected, except at the western end, where the western wall was tilted outwards. All the railway quarters were severely cracked; one of them had a north-south crack right across the house, opening up the roof. In the village, about one mile south of the railway station, nearly 50 per cent. of the houses collapsed.

CHAPTER XVIII.

ISOSEISMAL VIII, NORTH OF THE GANGES.

Champaran district.

Raxaul (27° 00′ : 84° 52′).—This village, the terminus of the newly constructed Nepal Government Light Railway, is in the extreme north of the headquarters subdivision of Champaran district.

Raxaul was not badly affected by the earthquake, and only a few old houses in the village collapsed. A house near the mill collapsed towards W.20°N. Pillars in the bazar fell towards N.15°E., and a revolving book case in Mr. Duncan's bungalow fell south. A temple, constructed in 1926 of good mortar and with roof girders, was undamaged except for minor cracks. Wells were filled with sand, and fissures and sand vents were common. A fissure running E.30°S.—W.30°N. cut across the bungalow of the British Legation, cracking the foundations; the outer walls of the bungalow were not damaged except above the fissures, but the inner walls were badly cracked.

Bettiah (26° 48′ : 84° 30′).—This subdivisional headquarters, with a population of 27,941 (1931), was not badly damaged, but it was isolated for more than 24 hours because of damage to the railway. The Hospital was ruined and several houses partially collapsed. Many compound walls fell. Fissuring in the neighbourhood of the tank was strong. Emission of sand was slight and faded rapidly to the north-west. It began to be worse about four miles east of the town towards Motihari. No emission of sand took place anywhere north-west of Bettiah along the Lauriya road. The Raj clock at Bettiah stopped at 14.12 hours (I. S. T.).

Both the north-south wings of the school building collapsed; the remainder of the building was rather badly cracked. The Rani's palace was not severely cracked, apart from the towers which were badly damaged and had to be pulled down. The north compound wall of the Durga Bagh temple fell. Two turrets fell towards the north-west and S.S.E. respectively. A fine newly built temple, built of Vindhyan sandstone which had been cut into long blocks and set upright, did not actually collapse, but the walls of the building bulged outwards—in the shape of a barrel to such an extent that the temple was unsafe.

Jagdispur (26° 42′ : 84° 35′).—This small village is about eight miles S.S.E. of Bettiah. The sides of a tank in this village collapsed into the water and a pole in the tank leaned due north. The lightning conductor on the Jagdispur temple was bent in a westerly direction and the temple itself was badly affected by east-west cracks which traversed the walls and the spire.

Majhowlia (26° 48′ : 84° 36′).—This station on the B. & N. W. Railway is about six miles east of Bettiah. The village was rather severely affected but the worst damage was at the sugar factory. The foundations of the factory were badly cracked and sank irregularly. The worst cracks were on walls aligned N.20°E. The east-west compound walls of the bungalows fell northwards. Most of the wells in the village were filled with sand and emission of sand from large fissures was quite heavy and extensive.

Saran district.

Gopalganj (26° 28′ : 84° 27′).—This town, a subdivisional headquarters two miles west of the Gandak river, does not possess any heavy structures, consequently the damage to buildings was not considerable. Most of the one-storey buildings escaped lightly.

Only hairbreadth cracks appeared over the arches of the northern verandah of the Criminal Court, a one-storey *pucca* building. The Post Office, a one-storey *kutcha-pucca* building, is aligned east-west, the north-south partition walls of the rooms were cracked near the corners and the outside walls were cracked slightly. Two almirahs standing against the western wall fell in an easterly direction. The jack-arches of the roof were not damaged. The Post Office clock stopped at 14·15 hours (I. S. T.). The one-storey *kutcha-pucca* Hospital had cracks, more particularly in the north-south partition walls. A ground crack about ¼-inch wide ran along the floor in an east-west direction. The east-west gabled parapet over a ward on the south side fell towards the south. At the Thana, a *kutcha-pucca* building, the north-south walls were cracked and the east-west walls were almost unaffected. Portions of the east-west boundary walls collapsed and fell to the north. The well in the thana compound was choked with sand. The Jail, a *pucca* structure, escaped with minor damage ; some of the walls developed slight horizontal cracks below the main arches. In the compound of Mr. Thorpe's bungalow there were several thin parallel cracks striking N.N.E. for about 50 yards, from which fine sand was ejected. A few cracks appeared in the bungalow walls, and ornaments in the rooms fell. Mr. Thorpe first felt an east-west movement which later changed to north-south. The football ground to the east of the High School was intersected by a number of six-inch wide north-south fissures, accompanied by faulting and ejection of fine grey sand. Water also flowed out of the cracks and inundated the field. The central north-south block on the eastern side of the school premises was badly damaged. The eastern wall was severely cracked and portions of it had to be dismantled. Portions of the roof collapsed. Some of the rooms on the eastern side of this block were further damaged by north-south fissures causing gaping cracks, three to four inches wide, in the east-west walls. The northern and western portions of the thatched roof of the one-storey *kutcha-pucca* Mission bungalow collapsed. Rev. A. L. Banks, of Gopalganj Mission, reported that the 20 feet long trunk of a tree, lying on the road south of the Mission bungalow, rotated through an angle of 60 degrees in a clockwise direction.

Gopalganj subdivision.—Fissures were present west of the Slump Belt in Gopalganj subdivision. North of Gopalganj the fissures ran parallel to the Saran Canal, over a zone about 2½ miles long, the fissures dying out northwards. Rev. A. L. Banks of the Gopalganj Mission very kindly supplied the following information about the fissures :—There were three distinct lines of fissures, each running almost parallel to the other and to the Saran Canal. One started at about Rajokhar, 2½ miles N.N.E. of Gopalganj and east of the Saran Canal and travelled S.S.E. through Nawada and then turned as the Saran Canal turns and ran S.S.W. through Manpura and Hajiapur and across the Baurali Road. The total length of this zone was two miles. The second started at Kotwa, about three miles north of Gopalganj, the fissures were very bad at Dhanuk Tola, and continued to the S.S.E. for about a mile and a half before turning towards the S.S.W. The fissures in

this zone were very deep and wide and continued as far as the extreme east of Gopalganj, damaging the local school building as previously mentioned. This zone of fissures was three miles in length. The third line of fissures started near Tirbirwa, about two miles north of Gopalganj and a few hundred yards west of the second zone, passed through Saduliahpur, keeping to the S.S.E. and then turned towards the S.S.W. before it reached Mathia, where the fissures were deepest on this line. This zone seemed to converge with the second near a mango grove, a little less than a mile N.N.E. of Gopalganj, where it faded away but reappeared on the south of the grove and passed through the Circle bungalow and across the High School playing field. The last two zones were on the western side of the Saran Canal. No fissures crossed the Saran Canal, although blow-holes were plentiful in the canal and in the low ground in its neighbourhood. The Subdivisional Officer of Gopalganj subdivision observed that villages or *bustees* surrounded by trees were less damaged by fissuring than those which were not surrounded by trees.

Manjha.—In this village, about six miles south-east of Gopalganj, the fall of buildings, especially of *kutcha* structures, appeared to be greater than at Gopalganj. The Manjha State building, a *pucca* three-storey structure, constructed on an elevated earth platform was completely shattered.

Hathwa (26° 24′ : 84° 24′).—At this village in the Siwan subdivision, 12 miles south of Siwan, resides the Maharaja of Hathwa, a wealthy zemindar. Hathwa suffered decidedly worse than Chapra and nearly as badly as Lakri. None of the two-storey buildings belonging to the Raj estate escaped, the three-storey palace of the Maharaja was badly cracked and damaged, but there was no total collapse of buildings, although in some cases partial collapses of buildings were noticed. One-storey buildings showed little damage as a rule. There were a few narrow ground fissures from which nothing was ejected. One or two wells in the village became choked with sand. The only buildings that successfully withstood the severe shaking at Hathwa were the Post Office and the Railway buildings. People at Hathwa agreed that the shock commenced sometime between 14.15-14.17 (I. S. T.) and was accompanied by a loud rumbling noise. Mr. B. N. Dutt, the Diwan of Hathwa Raj, stated that there was a preliminary tremor in which a slight up and down movement was felt for about five seconds; then there was a pause of about three to four seconds' duration, succeeded by a violent tremor and later a severe shock in which a side to side movement was felt. Mr. Dutt experienced a sensation similar to that when a ship is rolling and he felt it difficult to stand while the shock lasted. The duration of the last shock was about 45-60 seconds.

The main Palace is a lofty three-storey building consisting of two blocks. The southern and main block is aligned E.15°S., and the northern block is at right angles to it, the two being joined by a narrow central block. The south-western and the south-eastern corners of the northern block were badly damaged by east-west cracks traversing the width of the building and affecting the roof, floors and the north-south walls on the east and the west of the building. In the same block the east-west walls were also cracked together with the east-west arches of the northern verandah. The central block was completely undamaged, excepting portions of the eastern and the western parapets which partly fell. The main building on the south was badly damaged. The main portico on the south collapsed. The short north-south walls of the same block were badly cracked, especially those on

the first and the second floors. The northern end of the building was damaged by east-west cracks which traversed the length of the building, causing damage to the roof, floors and the north-south walls. The ground floor was slightly less damaged. The domes, supported on the parapets along the eastern and the western sides of the main building, were badly cracked. Other buildings such as the European Guest House, Reception Buildings, Temple, Old Fort, Tent House, Manager's bungalow, Diwan's house, Private Secretary's house and School were all damaged to a variable extent, mainly by cracks but occasionally by slight collapse. It was reported that an underground room at Hathwa and another at Lakri suffered no damage whatsoever.

Lakri (26° 22′ : 84° 23′).—This village is about 13 miles N.N.E. of Siwan. The District Board road from Siwan to Lakri was not affected by any fissure or sand vent. The residence of the Chairman of the Local Board was badly damaged; the north and the south compound walls collapsed, but the eastern and western walls were unaffected. In the main two-storey building the eastern and the western walls of the ground floor suffered worse than the other walls. The north-south walls on the first floor were badly cracked and had to be taken down, but the east-west walls were completely unaffected. Two corner rooms on the eastern side of this floor collapsed. The zenana was badly damaged by cracks and the roof collapsed.

Halimtolla (26° 22′ : 84° 25′).—At this village, north-east of Lakri, mud huts were badly affected. Several sand vents in the centre of the village emitted water and grey sand. Cracks were seen parallel to the cause-way in a north-south direction. Large fissures were present in the old bed of a river running through low-lying land to the east of the village. Carbonaceous grey sand and water were discharged from these fissures.

Musahara (26° 22′ : 84° 25′).—Another village nearby was rather badly affected. Many mud huts collapsed and some north-south fissures ran through the huts, raising their earthen floor six to nine inches. The fissures were four to six inches wide but no sand was ejected. Wells in the village were choked with fine grey carbonaceous sand.

Mirganj (26° 22′ : 84° 20′).—A village about ten miles north-west of Siwan was not much affected by the shock.

Chapra (25° 47′ : 84° 44′).—This town, the headquarters of Saran district, stands on an old bank of the river Gogra, close to its junction with the Ganges. The town is about five miles long from east to west, and its average breadth rarely exceeds one mile. The census of 1931 returned a population of 47,448.

Chapra was less affected by the earthquake than other district headquarters in North Bihar. Fissures or sand vents were absent. With the exception of a few old two-storey buildings in Katra bazaar, collapse of buildings in Chapra was negligible. The main damage to buildings was caused by wall cracks over arches and in other places of structural weakness, and in several cases the damage was so severe as to require demolishment of the structures. Portions of the Collector's bungalow and the bungalow of the Bettiah Raj collapsed. They were very old structures provided with heavy roofs. The Civil Surgeon's bungalow was badly cracked and had to be dismantled. The Circuit House, Bar Library, Criminal Court buildings, District Board office, and Municipal office were all damaged to a greater or less extent, and the upper storey of the Post Office building was badly

cracked. Some of the Hospital buildings were damaged, especially the upper storey of the Female Ward. In places the upper storeys of Wards Nos. III and IV and VII and VIII at the Jail were badly cracked. The Zilla School, a one-storey building, was rather severely damaged. Some private residences also suffered, roof parapets on two-storey buildings being especially weak. Plaster very commonly fell away from the walls. At the hospital bricks were flung from the southern extremity of the western parapet mostly to the west and some to the south. At the Panch Mandir temple the upper portions of some of the spires were twisted counter-clockwise and the main spire leaned west. At Gandhi's masjid the western turrets fell east. The flagstaff on top of the Criminal Court leaned westward and it was said that the flagstaff swayed east-west. The movements at Chapra were mainly east-west.

A noticeable feature in Chapra, as at Muzaffarpur, was that houses with brick or mud nogging raised on timber frames did not collapse so frequently as ordinary brick-built houses. Although in many instances the walls in such buildings were heavily cracked the timber frames were standing intact. In such cases the walls could be repaired without much difficulty. The best building of this type consists of a complete framework of timber, and the dead weight of the roof is shared both by the brick-work and the timber framework. Similarly it was noticed that verandahs raised on brick nogging had either collapsed or were badly damaged and brought down the walls to which they were attached by tie rods. In the case of verandahs supported on timber upright the damage done was very small.

Sonpur (25° 42′ : 85° 12′).—This village is on the right bank of the Gandak, close to its confluence with the Ganges. The Gandak bridge of eight 250-foot spans, close to the village, was not affected seriously by the shock.

Although a few mud huts in Sonpur collapsed or were damaged, *pucca* or *kutcha-pucca* buildings escaped lightly. The only building severely affected was the Dak bungalow, a lofty one-storey, part *pucca* and part *kutcha-pucca*, building, which partly collapsed, perhaps because of old age. In the Mina bazaar area a couple of two-storey buildings were somewhat badly damaged. The railway station buildings acquired a few cracks and a few tiles fell. The roof coping at the western end of the main station was tilted towards the west and that on the northern side fell north. According to the Station Master the shock arrived between 14.10-14.13 (I. S. T.) and it lasted for about three minutes. The shock was of moderate intensity. The railway staff quarters were shaken and a few cracks were sustained by the buildings here and there. All the houses north of the station suffered more than those to the south. Between Sonpur and Paleza, the pile bridge over the Mahi river was badly shaken necessitating repairs. All the walls of the Police barracks, a one-storey L-shaped *kutcha-pucca* building, were equally cracked. Portions of the roof of the thana verandah collapsed. Opinions were conflicting as to the direction of the shock in Sonpur.

Muzaffarpur district.

Hajipur (25° 41′ : 85° 12′).—This town, the headquarters of the subdivision of the same name, is situated on the eastern bank of the Gandak, a short distance above its confluence with the Ganges, opposite Patna. Its population in 1931 was 19,299. The worst affected parts were Banwaritolla (Mahajantolli), Hasankhan Mahalla, Minapur and Jaruha Saidpur, where quite a large number of *kutcha*

and old *kutcha-pucca* buildings collapsed or were so badly damaged that some had to be demolished. The bazaar area was not very badly damaged as many of the buildings here were newly erected. Four deaths were reported in the bazaar. The Subdivisional Officer's court, the Sub-Jail, the Municipal Office buildings and the District Board Dak bungalow withstood the shock quite well, but the Public Works Department bungalow did not escape. Portions of the roof of the Local Board Office collapsed. The central and old parts of the Criminal Court buildings were badly damaged; part collapsed, but the later additions escaped lightly. A stone pillar outside the High English School fell N.25°E. The railway station and the railway residential quarters were slightly damaged by cracks. There were a few fissures in alluvium striking N.35°E. and N.70°E. but no emission of sand. The Station Master recorded the shock at 14.15 hours (I. S. T.) and it lasted for three minutes. Its direction was N.W.—S.E. At first the ground movement was up and down followed by a side to side movement. He heard a rumbling noise like that of a motor car in motion. The Assistant Surgeon, Dr. T. P. Varma, said that he was inside the Jail Office at about 14.15 hours when he felt a rotatory movement beneath his feet and almost simultaneously heard a sound resembling the passing of a goods train. A few seconds later he felt the chair moving up and down, and then as he hurried out the movement stopped. The first shock lasted about 15 seconds, followed by a pause of about ten seconds after which everything shook violently. By this time he was outside the building and standing near the Local Board Office facing east and looking at the western side of the building. He saw the building swaying in an east-west direction. This second movement lasted about three minutes. The movement stopped suddenly as if a brake were applied.

The Mamu Bhanja tomb is about 275 years old. The entire structure was badly shaken. The turret on the north-eastern corner fell to the north and that on the north and both of those to the south of the tomb fell southwards. A turret near the north-eastern corner was twisted clockwise.

Lalganj (25° 52′ : 85° 10′).—This town in the Hajipur subdivision is situated on the left bank of the Gandak, 12 miles north-west of Hajipur. Its population in 1931 was 9,192.

Lalganj was the worst affected town in the Hajipur subdivision. A large number of *kutcha-pucca* buildings collapsed either partially or totally, many others were badly cracked. Mud huts suffered similarly, both in the town as well as in the villages on both sides of the road from Hajipur. The spire of a Siva temple south of Lalganj was twisted 15°-20° in an anti-clockwise direction about six feet from the top, and the broken portion moved slightly to the north. In a few two-storey *kutcha-pucca* houses at Pranganj the northern and the southern portions collapsed, leaving the eastern and the western walls standing but heavily cracked by cross fractures. The low lands were riddled with sand vents. Buildings were badly damaged over an area of three miles from Lalganj at such places as Yusufpur, Kamalpur, Jalalpur, Khan Jahan Chak and Daudnagar.

Darbhanga district.

Pusa Road.—This small way-side station on the B. & N. W. Railway is 24 miles from Muzaffarpur, eight miles from Samastipur, and about five miles from Pusa.

The station building received a few cracks and the floor of the parcel room was inundated with sand and water which issued from fissures. The western end of the station platform was traversed by a fissure a few inches wide and aligned N.15°W.—S.15°E., and from which some fine sand issued. Sanding took place on the adjacent ground and a shallow tank west of the station was filled with sand and water. The Station Master reports that the shock came from the north at 14.20 hours (I. S. T.); it lasted for three minutes and he heard a rumbling noise like that of a motor car in motion. The railway line was buckled slightly up and down and also laterally. Outside the station premises a few cracks appeared in the walls of the few *kutcha-pucca* houses, and plaster fell. Only one house about 1½ miles east of the railway station was reported to have collapsed.

Samastipur (25° 52′ : 85° 48′).—This headquarters town of the subdivision of the same name is situated on the south bank of the Burhi Gandak. Population in 1931 was 1,931.

About one-third of the two-storey buildings at Samastipur either collapsed or were badly cracked; the area between the river bank on the north and the railway on the south was the worst affected. The maximum destruction was confined to the bazaar area, where a number of two-storey buildings, mostly *kutcha-pucca*, partially collapsed and others were badly damaged; about 30-40 per cent. of the buildings in the bazaar either collapsed or were badly damaged. Most well-built structures escaped with minor damage, *e.g.*, the Court buildings and most of the buildings south of the railway line. The sugar factory north of the railway line was badly damaged both by actual shock and by ground fissures striking N.W.—S.E.; the upper 40 feet of the 140 feet high masonry chimney fell towards the N.N.E., and the boundary walls aligned east-west fell either to the north or south. One of the gate pillars at a railway bungalow fell north-east. At a mosque south of the cemetery a turret fell due west, another fell S.20°W. The bell at All Souls' Church was flung from a height of 30 feet above the ground to a distance of 20 feet in a direction S. 35° W.; a brick cross was thrown in a similar direction. The church partially collapsed. Other important buildings which partially collapsed included the Roman Catholic Church, the European Club and the Municipal buildings. The railway quarters and bungalows escaped but most of the sheds of the railway workshops suffered. In the majority of cases long walls aligned W.N.W. were bodily pushed a few inches in a southerly direction above a height of 1½-2 feet from ground level. The railway bridge on the Burhi Gandak was damaged but the floating bridge escaped. Fissures, together with ejected sand, occurred at several places in Samastipur both north and south of the railway line; at the polo ground a fissure several inches wide, from which sand was ejected, was 300 yards long and had a strike N.50°E. Sand was a foot deep at the northern end of the polo ground. Several wells were infilled with sand. The clock of the Telegraph Office stopped at 14.15 hours (I. S. T.). The Post Master heard a rumbling noise and he was knocked down. According to the Second Officer the main shock came from the west, travelled eastwards, and was accompanied by a rumbling noise. He was facing north and felt a swaying movement from side to side. The whole town, according to him, was without water for some time, as only two or three wells were functioning. After the main shock a little water remained in the wells but the water dried up within the next 24 hours. Fissures had no consistent strike.

Rusera Ghat (25° 45′: 86° 02′).—This town in Darbhanga subdivision is situated on the east bank of the Burhi Gandak just below its confluence with the Kamla (Baghmati). Population in 1931 was 8,869.

About 30 per cent. of the *kutcha-pucca* and *kutcha* buildings collapsed; the rest of the houses were slightly damaged. In the majority of buildings which collapsed walls aligned east-west fell, but in others north-south walls also collapsed. The station buildings and the quarters of the railway staff suffered but slightly. The solid brick-built globe on the top of the Khublalpurbe Temple fell towards the north-west and portions of the upper walls fell mostly towards the west and north-west. The lower walls fell mostly northwards. According to the Station Master the shocks came from the north at about 14.12 hours (I. S. T.) and travelled south. Three shocks were felt during the subsequent night. The Post Master was of the opinion that the shock came from the north-west sometime between 14.15-14.20 hours. Most people in the bazaar agreed that the shock came from a north-westerly direction and was accompanied by a loud rumbling noise. Many people could not stand on account of the violence of the shock. No sand or large fissures were noticed at Rusera, although these were present in the neighbouring villages.

The railway bridge over the Burhi Gandak is about a mile west of Rusera Ghat station and is aligned east-west. There are nine piers centred at 87 feet, the abutment spans being 40 feet. The measurements of one of the central piers are: depth of the well 60 feet, height of pillar from river bed 43·75 feet, total height 103·75 feet. The third and the fourth pillars from the east bank were tilted south and were out of alignment 1′ 6″ to 2′ 0½″ from their respective centres. The fifth was tilted about 2′ 10″ towards the east. The sixth pier was tilted 2′ 0½″ towards the south and the well was thrown out of alignment towards the south. The fifth and the sixth piers were on the lines of fissures which cut the west bank of the river, producing a downthrow of three feet towards the east. The rails showed a maximum shift of 11″ in an east-west direction. The bedstone of a 40 feet girder on the first pillar at the east bank was thrown 12″ towards the east and then heaved back three inches, so that the final displacement was nine inches towards the east. The directions of movement in this bridge were north-south as well as west-east.

Dalsingh Sarai (25° 42′: 85° 54′).—This large village in the Samastipur subdivision is 15 miles from Samastipur. Quite a large number of *kutcha* houses in the bazaar area collapsed. The upper storeys of about a dozen two-storey *kutcha-pucca* buildings with thatched roofs collapsed, and two or three such buildings totally collapsed. In all of these cases the north-south walls fell either towards the east or the west, while the east-west walls were left standing. In some cases pillars fell east or west, and the boundary wall, aligned north-south, of a house in the bazaar fell, but the east-west walls were standing. Several turrets on the roof of one house fell to the west and one fell east. The spire of an old temple fell in a south-westerly direction. In a number of cases the western side of a house was worse damaged than the other sides. The walls of several well-built *pucca* buildings were badly cracked. The indigo factory and the manager's bungalow were badly damaged, the bungalow chimney fell east. The cigarette factory was also considerably damaged. The Assistant Sub-Inspector of Police remarked that the shock lasted for about five minutes.

Proceeding north from Teghra by rail very rare patches of sand vents and sand were noticed between Teghra and Bachhwara. No major damage was noticed at Bachhwara station, but a few dismantled buildings were seen in the village close by. Within a mile north of Bachhwara sand vents and patches of sand increased in number followed by a fairly clear tract up to and beyond the bridge on the Balan river.

Monghyr district.

Teghra (25° 30′ : 85° 54′). –This small village in Begusarai subdivision, about 12 miles W.N.W. of the subdivisional headquarters, escaped somewhat lightly from the earthquake. The few houses that collapsed were built of mud and brick and possessed thatched roofs; no well-built *kutcha-pucca* buildings collapsed. The Dak bungalow was practically undamaged as also was the Hospital. About half a dozen or so houses in the bazaar area collapsed and a few near the railway station were cracked. Two of the turrets on the eastern parapet of a mosque fell to the south and two such on the northern side fell to the west. The Sub-Inspector of Police, Babu Jitan Prosad, stated that the shock lasted for five minutes and started with a side to side movement which increased in violence. A deep rumbling noise, like that of an aeroplane overhead, was heard simultaneously with the arrival of the shock.

W.N.W. of Teghra and a mile west of Bachhwara station, some sand vents and cracks were noticed and a diversion had to be made on this account. Several huts and walls collapsed south of mile-post 141/1, near Mohiuddinnagar railway station. Further west, in a village between mile-posts 149/16-18, many mud huts collapsed. A number of mud huts collapsed near the railway station at Sahadai Buzurg, but the station building appeared to be unaffected.

Begusarai (25° 26′ : 86° 09′).-- This headquarters of the subdivision of the same name in Monghyr district is about five miles north of the Ganges. Its population in 1931 was 7,739. In the bazaar area some *kutcha-pucca* and *pucca* buildings collapsed, especially the upper storeys of tall buildings, but the number was not large—certainly not larger than that at Khagaria. On the other hand, *pucca* and semi-*pucca* buildings at Begusarai were more damaged than similar buildings at Khagaria. Begusarai was immune from ground fissures and emission of sand. From a comparative study of the fall of walls it seemed that the principal direction of ground movement was north-south. The Subdivisional Officer felt an up and down movement followed by a side to side movement and thought that the shock travelled from north-west to south-east.

Begusarai subdivision.—Although included within isoseismal VIII a number of villages north of Teghra were badly damaged. North of the Balan river practically every house, mostly mud huts, had been more or less affected. Many were razed to the ground. The effects of fissures in these villages were negligible although in one of them, Bhawanipur, a few sand vents were noticed and several wells were choked with sand and fine silt. The level of the water in the Balan river was found to be three or four feet above the normal height for February.

Khagaria (25° 30′ : 86° 30′).—This town, in the north of the Monghyr subdivision, is situated along the river Gandak at a distance of about three miles from its confluence with the Ganges. Most of the damage in Khagaria was confined

to the bazaar area, which runs east to west parallel with the river, and here quite a larger number of houses collapsed and many were badly damaged. The buildings thus affected were mostly *kutcha-pucca*, of faulty workmanship and constructed of weak materials. Several newly built *pucca* houses, both one- and two-storey, escaped damage, beyond slight plaster cracks. In most of the houses the walls aligned north-south collapsed, the east-west walls were left standing but cracked. In such cases the fall of the north-south walls took place mostly towards the east. Occasionally east-west walls fell. A large number of houses totally collapsed—the roofs falling vertically and the walls in all directions. Where the upper storeys had collapsed and the ground floors were left standing, the east-west were usually cracked more heavily than the north-south walls. The majority of cracks were confined to the east-west walls. In some houses in the bazaar the south-western and the north-western corners collapsed. In the case of the boundary walls the number of north-south walls which fell either east or west mostly east- exceeded the number of the east-west walls, which fell either north or south. In one house four out of six pillars of the eastern verandah fell towards the east, while that at the extreme northern end fell to the north and that at the southern extremity was standing. In another house pillars fell to the west, while in the case of a house near the *ghat* some of the pillars of an eastern verandah fell eastwards while that at the northern end fell to the north. In a temple near the river bank, some of the pillars fell to the north and some to the west while others remained standing. Although *kutcha-pucca* buildings suffered badly, thatched houses built on timber frames survived the earthquake shock remarkably well.

If the total number of ruined houses is taken into consideration, it would appear, at first sight, that the shock at Khagaria was very great, but recognising the prevalence of weak structures the shock was much less intense than at Darbhanga or Muzaffarpur. Judging from the cracks in buildings and the fall of objects the shock had a strong westerly component. Fissures and sanding occurred only along the river bank, running parallel to it, and in the surrounding low lands not very far from Khagaria.

In the town itself no wells were choked with sand; the water level in wells rose soon after but later went down to normal. The Post Master reported that the arrival of the first shock took place at 14.13 hours (I. S. T.); the main shock lasted for about three and a half minutes and was heralded by preliminary shocks lasting for 15 seconds and followed by an aftershock lasting for one minute. Bottles on shelves in the Post Office fell eastwards.

The Burhi Gandak railway bridge, about two and a half miles south-west of Khagaria, has seven piers between the two abutments and is aligned N.25°W.—S.25°E. The fourth pier from the south bank was cracked at a height of 12′ 6″ from the shoal on which it was standing at the time, the bottom portion was shifted in a direction 5° W. of N., a distance of one foot. The measurements of the pillar are as follows:—Cross section 21 feet by 9 ft. 6 in. height of the pillar above the water level 30 feet, from the top of the rail level to the top of the well 44·70 feet, height between the top and the bottom of the well 90 feet, load supported by the pillar 67 tons approximately. The top of the well was about 15 feet below the water level at the time. The first pier from the north bank was cracked about three feet above the sandbank but it did not move and there were two vertical cracks four feet high.

Purnea district.

Araria (26° 06′ : 87° 24′), *true name Basantpur.*—This town is the headquarters of the subdivision of the same name in the north-west of Purnea district, and is on the right bank of the Panar river. The damage was not great, almost all the *pucca* buildings were unaffected except for slight cracks. Damage was confined to poor structures and only one very old house collapsed. Most houses built of bamboo and thatched huts were unaffected. The damage was mainly along the Panar river, east of the village, and there were a considerable number of fissures along the river bank.

Several roads radiate from Araria. Along the road running almost due south from Araria to Purnea there were no sand vents and rare fissures. Several timber pile bridges were damaged on the road to Raniganj, west of Araria, because of the upward movement of the piles, but screw pile bridges appeared to be undamaged. At Joki Hat, east of Araria, the District Engineer reported the collapse of the Inspection bungalow. North of Araria two steel girder bridges span the river, and piles in these instances were badly out of line. At Madanpur three *pucca* houses developed small cracks in the walls and further north a few ground fissures were seen with a little ejected sand. On the Jogbani rail line, north-west of Araria, most of the fissures ran across the line and, according to the District Traffic Manager, were aligned N.E.—S.W. Near Jogbani the screw pile bridges were damaged by the piles subsiding and the river banks closing in, causing girders to drop. The bridge near Forbesganj had masonry piers, the central pier subsided bringing down the girders. In this case there was very little cracking of the piers. Rails were bent in certain sections of the line away from the bridges, and many sleepers moved as much as four inches either way.

Bhagalpur district.

Bangaon (25° 52′ : 86° 32′).—At this very ancient village, about five miles west of Saharsa, fields were overrun by fissures and sand vents. All the wells were choked with sand and the few *pucca* houses were cracked, the walls of two of them collapsing. Thatched mud huts were also damaged. The thana was cracked but the hospital was not damaged. Both sides of the District Board road from Bangaon northwards were overrun by sand vents and fissures as far as Panchgachia. Some of these vents were quite large.

Saharsa (25° 53′ : 86° 36′).—In this village four *pucca* buildings collapsed and others were cracked, but not badly. The P. W. D. Inspection bungalow, a fine building, had a few cracks on the north-south walls. The school building was badly cracked and the walls were leaning either to the north or to the south; the southern verandah collapsed. Cracks in the ground ran east-west. The American Mission Church, a fine *pucca* brick building, was undamaged, except for a few tiles of the roof which fell, but the bungalows were cracked.

Kishanganj (25° 41′ : 86° 58′).—This village, about five miles W.S.W. of Behariganj, was formerly the headquarters of Thana Kishanganj, but owing to the encroachments of the river Kosi the thana was shifted elsewhere. The walls of a few *pucca* houses were cracked. No collapse of houses was noticed.

Alamnagar (25° 34′ : 86° 56′).—This village is situated about seven miles south-west of Kishanganj. A few old *pucca* houses collapsed. Traces of many fine tanks

and the earthenwork ramparts of forts built by the Chandil chiefs, the former owners of the land, are still visible.

Phulaut (25° 33′ : 87° 00′).—About four miles S.S.E. of Alamnagar. Three or four old *pucca* houses collapsed in this village.

Darjeeling district.

Darjeeling (27° 03′ : 88° 18′).– The summer capital of the Government of Bengal and the headquarters of the district of the same name, this town is situated in the Lower Himalaya and has a total area of nearly five square miles. The difference between its highest and lowest points is about 2,000 feet, Katapahar being 7,886 feet and Lebong 5,970 feet. The town is situated on a long narrow ridge with great valleys, 4,000 to 6,000 feet deep, on either side, a number of small spurs projecting from the flanks.

The town was severely shaken during the Assam Earthquake in 1897, and experienced a great landslip in 1899. Time records for the 1934 shock, obtained from railway stations and telegraph offices, varied from 14.10 to 14.15 (I. S. T.) for different parts of the hills, but there was some agreement for 14.14-14.15. The early tremors were followed by a succession of waves of considerable amplitude and long period; there was a general consensus of opinion that the first shocks were west-east, followed by roughly north-south and later by a distinct gyratory movement of the ground. There was no clear proof of any vertical movement. At the Darjeeling Cemetery a marble cross, 2½ feet high, was tilted 10° to the west, another near it was rotated 5°, only one large cross, rather loosely set in a socket in the base, was thrown bodily to the N.N.W., and another heavy marble ornament was tilted 10° N.N.E.

Loose objects, such as statues, fell from their pedestals in various directions impartially at the St. Joseph's College, but a slender masonry chimney, 12 feet high, in the same building was standing. Two pianos, placed against opposite walls in a room in Mt. Harman School, were propelled forward, coming to rest in the middle of the room and meeting at an angle. From a room in the Mt. Everest Hotel the fire was hurled out of the hearth in a southerly direction. At the Singamari House, three cupboards were overthrown and fell forward, each one in a different direction, the contents of one of these being shot out in a direction rather diagonal to the fall. Two iron bedsteads were thrown out bodily through the broken east-facing wall of a room in the upper storey of a bungalow in the Jalapahar Cantonment. A chimney in an adjoining bungalow fell towards E.20°S., and another close by was broken and its top portion rotated on the base in a clockwise direction.

Houses were damaged by bulging and collapse of the east-west walls, allowing the centre and the roof to subside or fall bodily. Cracks in the houses generally gave no sure guide as to the nature and direction of the earth movements felt at Darjeeling. Much of the damage to houses still standing was caused by massive masonry chimneys falling in all directions, crashing through the roofs and upper floors. The destruction of buildings such as the Government House, Campbell Cottage, Rockville Hotel, the Cantonment buildings of Jalapahar and Lebong, Burdwan House, the Jail, the Government High School, and to a lesser extent the Kutchery, the Gymkhana Club and the Planters' Club, Collinton, etc., could be ascribed to age, weak construction and poor foundations. The majority of these

buildings were old, they were constructed of heavy, undressed stone-masonry set in mud or in poor quality mortar, while their foundations were often laid in loosely aggregated sub-soil.

In the area of maximum damage, even in the midst of fallen houses, ferro-concrete structures stood almost unharmed, as also did well-constructed recent buildings of brick or dressed stone. The Katapahar bungalows, which are more recent than the Jalapahar buildings and which have their foundations on an outcrop of solid rock, escaped wreckage. Stephen Mansion, a tall, four- to six-storey re-inforced concrete building, perched on the edge of a *khud*, withstood the shocks almost completely undamaged; such also was the case with the new Victoria Hospital and the St. Paul's School, where the only damage was the fall of a chimney or two and some wall-cracks. The bazaar and Chandmari quarter of the town, with its recent well-built cement houses, escaped any material harm.

Visible damage to buildings was largely confined to the immediate vicinity of fissuring in the ground, the part of the town to the west suffering much more than the area to the east. While the chief damage to the main ridge seemed to have been due to earth-waves which proceeded from a westerly direction, in the spurs a roughly north-south rocking of the ground was apparently responsible for the major part of the destruction.

The most noteworthy effects of the earthquake were confined to the crest of the Darjeeling ridge and its outlying spurs, mostly on the western side. A ground crack, or rather a series of more or less unidirectional, intermittent cracks, roughly N.N.W.- S.S.E., could be traced along the main ridge from the Mt. Harman School, through Birch Hill and Government House from where it continued, after a slight change in orientation (N.15°E.—S.15°W.) to as far as the Medical Officer's bungalow in the Jalapahar Cantonment. The crack did not extend to Katapahar. The fissures on the crest of the spurs had varying directions and were generally oblique to the crack in the main Darjeeling ridge. Those traversing Batasia spur were aligned N.N.W.—S.S.E.; the Bloomfield Police Lines had an E.S.E.—W.N.W. fissure with a subsidence of five to eight inches on the north side; a longitudinal crack was traced along the crest of the Rose Bank spur in a W.N.W. to E.S.E. direction, extending towards Sidraphong; the Jail and the Government High School spurs had a series of branching cracks, while the long northerly Lebong spur was cut by another series of parallel cracks, trending N.20°W., generally three to four inches wide, with local sinking of about six inches on the eastern side of the crack. Both series of cracks varied from one-third of an inch to three or four inches in width. Occasional local subsidence along them was due to differential sinking or compression of the loose sub-soil. A close examination of the cracks, especially on the main Darjeeling ridge, showed them to be superficial and restricted to the top layers of the sub-soil.

Darjeeling Hills area.—The tea gardens and estates, scattered over outlying westerly and south-westerly spurs of the Darjeeling hills, sustained considerable damage to property. A number of the older bungalows of heavy stone masonry were either shattered and in part collapsed, or were uninhabitable as a result of extensive cracking. Ground fissures, one or two of them over a mile in length, were reported to have formed along the spurs. The railway station at Tindharia, situated on a bad site at the head of a steep *khud*, and built on poor foundations, was badly wrecked. A ground fissure, over 300 yards long, trending N.E.—S.W.

was observed beneath the station yard. Cracks parallel to this traversed the station building. The railroad between Tindharia and Kurseong, along with a considerable area of ground in the Teesta Valley to the east, was practically in an earthquake shadow.

Kurseong, though strongly shaken, did not suffer appreciable damage, a fact which may be attributed in large measure to its houses being more commonly founded on rock or firm ground.

At Rimbeck the school collapsed together with parts of the walls of *pucca* buildings. Most of the village is built of timber and was undamaged.

At Budhwari (27° 06′ : 88° 07′) there were cracks in the police quarters, but the wooden houses escaped damage.

CHAPTER XIX.

ISOSEISMAL VIII, SOUTH OF THE GANGES.

Patna district.

Dinapore (25° 38′ : 85° 03′).—This town, the headquarters of Dinapore subdivision, is about six miles west of Patna. Dinapore is also a divisional headquarters of the East Indian Railway and the military headquarters of the Patna district.

The damage at Dinapore was rather less than at Patna. Verandahs, roof copings and porches collapsed, and walls, particularly over arches, were badly cracked. In the cemetery the movements were sufficiently severe to crack and displace portions of obelisks; in one case the top of an obelisk 12 feet high and three feet by six feet at the base was rotated 1·5 inches anti-clockwise above a plane four feet from the base.

Fatwa (25° 30′ : 85° 19′).—This village in the Barh subdivision had a population of 9,393 in 1931. The village suffered no great damage. Such semi-*pucca* buildings, as the school and station, were cracked by east-west movements, and some roof copings fell.

Bakhtiarpur (25° 27′ : 85° 32′).—A few buildings were damaged by cracks.

Bikram (25° 27′ : 84° 51′).—This small village in the Dinapore subdivision showed the unusual feature, for south of the Ganges, of ground fissures and sand vents with subsidence of buildings. In the thana building the direction of the cracks indicated east-west movements. From small ground fissures within a few feet of the thana, sand and water was emitted up to a height of three feet. Water in the well in the thana compound rose to the surface and overflowed and the well was filled with sand when the water subsided. The well was brick lined and the usual water level is 20 feet below the surface. In some places water emerged for about five minutes after the movement. Another well was smashed and the brickwork broken. A fault striking east-west and 150 yards long followed one side of the road in the bazaar; the ground to the north sank four feet taking houses with it. Water and sand spurted from this fissure up to a height of four feet. Another fissure in the road also had sand and water vents along its course. From still another fissure considerable sand and water were thrown out to a height of six feet, for about six minutes, after the quake had stopped. The fissure crossed the District Board road and caused subsidence on both sides of it. Most of the villagers agreed that the movement was definitely east-west.

Hilsa (25° 19′ : 85° 17′).—This village in Bihar subdivision is 13 miles south of Fatwa. Buildings were slightly cracked, and four houses out of one hundred collapsed. The movements were mainly east-west.

Bihar (25° 11′ : 85° 31′).—This town, from which the name of the Province is derived, is the headquarters of the subdivision of the same name and had a population in 1931 of 46,994.

Many buildings were quite severely cracked and a few *kutcha* houses collapsed. The damage placed the town on the edge of isoseismal VIII. Most of the buildings

were old, but the General Hospital, built in 1926, had large cracks in all the walls, especially on the northern and southern sides. Occasional verandahs and roof parapets collapsed. The general opinion of the hospital staff was that the movements took place S.E.—N.W.

Luckeeserai (25° 12′ : 86° 06′).—This small town in the Monghyr subdivision is situated on the western bank of the Kiul river, a tributary of the Ganges.

Luckeeserai was only slightly affected. North of the town some small fissures and sand vents were arranged parallel to a *nulla* or ditch about 80 feet wide and 8 feet deep. A little sand and water was ejected during the opening and closing of the fissure, to a height of five feet according to a villager. Other cracks to the north discharged water. On the site of an old well, now infilled, water rushed out to a height of four feet. The water spurted for two minutes and continued to well up gently for some hours. During the shock the Kiul river, which flows north and has a very strong current, became very turbulent. In the bazaar, roofs of a few verandahs fell and a few walls collapsed. Most of the movements in the bazaar were east-west. In some of the better buildings such as the Thana, Registry Office, Dak bungalow and station buildings, cracks were developed in the walls. The roof coping on the western side of the railway station fell. The Station Master remarked that the water in the river near the bridge receded from mid-stream towards the banks and sand was thrown up from the middle. Small sand vents and cracks formed on the banks near the bridge.

Bhagalpur district.

Bhagalpur (25° 15′ : 87° 00′).—This is the chief town and the administrative headquarters of the district of the same name. Its population was 83,847 in 1931.

The damage at Bhagalpur was similar to but of less intensity than that along the river front at Patna. Portions of buildings collapsed, many were so severely cracked as to be completely ruined. The greatest damage took place close to the river, the intensity rapidly diminishing southwards. A certain amount of damage was done to light buildings in the bazaar but not comparable with the damage suffered by heavy government and private buildings. The Church, the Criminal Court buildings, the Executive Engineer's residence (old Burdwan House on jack arches), the Commissioner's office and part of the roof of his house, the Judge's Court, the District Board office, the Local Board office, portions of the jack arched roof in the Central Jail, the old Circuit bungalow, the old Post Office, the Training School, the Munsiff's Court, the railway station, the railway offices (where two persons were killed), the C. M. S. School and the Club House were seriously damaged; many of these buildings collapsed in parts. A large number of old private buildings suffered similarly, such as the house of Rai Bahadur Dip Narayan Singh, Raja Sib Chandra, the late Babu Chandra Sekhar Sarkar, the late Babu Suryyanarayan Sinha, Rani Chandrabati and the fine newly built two-storey house of Rai Bahadur Suhhrtaraj Rai. The old T. N. J. College buildings as well as the newly built T. N. J. College building (built in 1920-21) near Champanagar, and the C. M. S. School were also badly damaged. There were few cases of houses levelled to the ground. Some fine built structures, such as the new Circuit House escaped with no more than occasional faint cracks. The clock of the tower near the hospital stopped at 14·15 hours (I. S. T.). Time records vary from 14·15 to 14·20

hours (I. S. T.). The noise, accompanying the tremor, was variously described as resembling a ground roller moving on a concrete floor, 'muffled guns', or a 'heavy lorry' on the road. The Principal of the C. M. S. High School said that the school clock tower definitely swayed in a W. N. W.—E. S. E. direction. The verandah pillars fell west and a pillar near the school fell towards E. S. E. Most of the fountains at Mr. Dip Narayan Singh's house fell towards the east and all the ornamentations were broken and fell east. The verandah pillar of the house also leant towards the east and a portion fell. The Headmaster of the Zilla School said that the school building rocked definitely in an east-west direction. The top ten feet of the tall chimney at the Shaw Flour Mill fell towards the east. All the pinnacles around the English church walls crashed and fell towards the east.

As a rule north-south walls crashed rather than east-west walls. Many objects free to fall in any direction fell to the east, but occasional pillars were tilted to the west. Clocks with east-west swinging pendulums were not affected, but those placed in other directions stopped. The evidence throughout the town indicates clearly an east-west to E. S. E.—W. N. W. direction of movement. Bhagalpur is on a thick, highly compact, yellow clayey loam, which served as a rigid foundation to many of the river-side buildings, accounting for the absence of ground cracks. According to the *Statesman* five persons were killed and 30 injured at Bhagalpur.

Sultanganj (25° 15′ : 86° 45′).—This small village in Bhagalpur district is situated close to the south bank of the Ganges. There are two outcrops of granite gneiss on one of which at the river bank there is a Muhammadan mosque. The second and larger one is occupied by a temple of Ghaibnath Siva. About a quarter of the houses at Sultanganj totally collapsed and the remainder were cracked. Houses near the river suffered far more severely than those further south. Of the houses that collapsed, the majority fell towards the west. All these houses were built entirely on alluvium. Mud huts were the least damaged. The water tower near the river bank at the north-west corner of the town was badly fractured near the base and was leaning towards the east. A gate at the H. E. School fell to the east as also did parts of the tower. At Sultanganj, the east-west movements were very prominent.

The temple of Ajgaibi Nath situated on an outcrop of gneiss forming an island in the river was quite undamaged, not even cracked, but the roof of the small *dharamsala* fell. The temple was built over 135 years ago and is older than the mosque. The Sultanganj Sahi mosque, not quite so old as the temple, is also built on gneiss at the edge of the river, which flows along its northern and western foot. The building fell away on the western side, especially at the south-western corner.

Ghogha (25° 12′ : 87° 12′).—At this small village, 13 miles east of Bhagalpur the intensity of the shock was not great. East of Bhagalpur the intensity diminished gradually. The roof coping of the railway station, on the eastern wall, fell down. There were diagonal cracks in the north-south walls, especially at the eastern end. The station cabin was also affected in the same way and the eastern and the western walls were cracked.

Colgong (25° 16′ : 87° 14′).—At this small town on the right bank of the Ganges there are several detached patches of gneiss. Very few structures collapsed here, but the fracturing was severe. Structures built on solid rock were much less damaged than those built on alluvium. The movement was apparently more in a north-west direction than at Bhagalpur.

CHAPTER XX.

ISOSEISMAL VII, NORTH OF THE GANGES.

Champaran district.

Lauriya Nandangarh (27° 00′ : 84° 24′). This small village in the Bettiah subdivision is situated some 14 miles north-west of Bettiah. The village contains the well-preserved Lion Pillar of Asoka which, although over 2,000 yards old, is in an excellent state of preservation and its massiveness and exquisite finish afford striking proof of the skill and resource of the masons of Asoka's time. The shaft is formed of a single block of polished sandstone, 32 feet 9½ inches in height, with a diameter of 35·5 inches at the base and 26·2 inches at the top. It supports a bell-shaped capital six feet ten inches high, surmounted by a circular abacus supporting the statue of a lion. The pillar remained undamaged except that the lion is reported to have shifted on its axis in an anti-clockwise direction.

The village was not badly affected. Towards the north-west the decrease in intensity outwards from the epicentral tract was more rapid than in most other directions. This rapid decrease in intensity is partly intrinsic but partly also apparent, since the clay soil appears to have had a damping effect. The 90 feet high brick chimney of the Lauriya sugar factory, built some 27 years ago and recently condemned, escaped without a crack. The old sugar factory, built of brick set in mud, was scarcely affected. In Mr. Bird's house, water swilled out of a glass fish container towards the north.

Saran district.

Siwan (26° 13′ : 84° 21′).—This town, the headquarters of the subdivision of the same name, is situated on the east bank of the river Daha. Its population in 1931 was 14,215.

Siwan was unaffected by fissures or discharge of sand. Few houses collapsed. Damage to buildings consisted mainly of cracks in both north-south and east-west walls. Several turrets were thrown in an easterly direction. Two double storey buildings were heavily damaged, and the upper storeys of two houses partially collapsed. The Criminal Court and the Jail buildings were slightly damaged. The masonry globe supported on a marble canopy of a Shiva temple was projected to the north. A sandstone slab resting on the uppermost spire of Shubharat Shah's temple, and supporting copper globes resting one above the other surmounted by a copper flag, was twisted in a counter-clockwise direction. A globe on the turret on the north-eastern corner of a mosque was cracked near the base and leaned towards the north-west, another on the south-eastern corner met with a similar fate and leaned towards the south-east. Several turrets on the eastern side of another mosque fell to the east.

Purnea district.

North bank of the Ganges.—On the north bank of the Ganges, opposite the Bhagalpur-Sahebganj tract, the earthquake effects were not of appreciably greater

intensity, although a sharply marked increase in the intensity became perceptible westwards of Thana Bihpur. Between Katihar and the latter place, however, no considerable damage was observed either on the railway line or in the villages but the absence of masonry structures, except railway stations at intervals of seven to nine miles, made it difficult to observe the effects in the soft, much-cultivated alluvium and to assign values to their intensity at different places. At Naugachia some *pucca* buildings, with an east-west long axis were much affected: walls facing south bulged out and become detached at the corners, though the railway station and staff quarters were unharmed. Some cracks developed along *nalas* and river beds. At Kursela the effects were not pronounced, a solitary masonry arch, 15 feet high and 10 feet in span, was standing intact. At Katihar, scarcely any earthquake effects were perceived, their absence being remarkable in view of the damage in the areas to the north and west. The slender minarets of a mosque were intact, so also were the chimneys of the factories, which sustained a few wall cracks. In the country lying between Katihar and Parbatipur the intensity of the shock steadily diminished.

Katihar (25° 30′ : 87° 36′).—This large village is situated about 18 miles south of Purnea, and had a population of 15,864 in 1931, excluding the railway settlement, the population of which was 3,054. It is the chief railway centre in the district, being an important junction of the B. & N. W. Railway and the Bihar section of the Eastern Bengal Railway.

The slight damage at Katihar indicates how rapidly the earthquake effects diminished east and south of Purnea. A few small cracks appeared in buildings. The Sub Inspector of Police felt a N.E.—S.W. movement. The brick piers of the Kosi bridge, three miles west of Katihar, subsided slightly. Slight cracks appeared in buildings in the villages east of Katihar.

Kishanganj (26° 06′ : 87° 56′).—This town, the headquarters of the subdivision of the same name, had a population of 8,946 in 1931.

Proceeding east from Purnea towards Kishanganj the road, after about three miles, showed no certain signs of any damage. One or two depressions which might have been caused by the earthquake were occasionally noticed up to about the 15th mile. Kishanganj itself did not suffer from any noteworthy damage. Only the thana, the jail, the Sub-Registrar's office and the Munsif's court were slightly cracked. The south-western end of the hospital was badly cracked and had to be pulled down. There were no ground fissures in the village. The Subdivisional Officer stated that the movement was definitely east-west.

Islampur, a village about 20 miles north-east of Kishanganj, and Thakurganj, about 13 miles N.N.W. of Islampur, were affected about the same as Kishanganj.

Bahadurganj (26° 15′ : 87° 49′).—This village is about 14 miles from Kishanganj in a north-westerly direction. Some of the buildings were badly cracked. The Sub-Registrar's office, a *kutcha-pucca* structure, was damaged. The hospital was slightly cracked as also the Inspection bungalow. The Sub-Inspector's quarters were condemned. Several very small fissures, up to ten feet in length, were present around Bahadurganj but no sand was thrown out.

Dighalbank, a village at the extreme north of Kishanganj subdivision and about 12 miles north of Bahadurganj, suffered to the same extent as the latter village.

CHAPTER XXI.

ISOSEISMAL VII, SOUTH OF THE GANGES.

Gaya district.

Gaya (24° 49′ : 85° 01′).—This town, the administrative headquarters of Gaya district, is situated on the western bank of the Phalgu. The town is divided into two parts—the old town of Gaya and the modern administrative town of Sahibganj, laid out at the end of the 18th century and containing the civil offices, residences of government officers and business men of all classes, and public buildings. The modern town with its straight, broad streets contrasts strongly with the old town, riddled with narrow lanes and crooked alleys, 'flanked by tall masonry houses with overhanging balconies or frontages of carved woodwork black with smoke and age'.

The intensity of damage around Gaya was slightly greater than in places both to the north and south. The worst affected portion of the town was Gayawalbigha, where many mud huts with heavy tile roofs fell. At the gaol the upper parts of two three-storey blocks were badly cracked. The old portion of the town near the Vishnupad Temple was seriously affected; many buildings in the town were cracked and a few porches fell. At Nazraganj a few houses along the river were damaged; some houses, 200 years old, and built of narrow bricks, were undamaged. A verandah on the western side of Andar Gaya, the oldest part of Gaya, fell. Some very old buildings, built 400 years ago, and previously cracked, collapsed. Many tall buildings had to be abandoned. Part of a house in the Civil lines fell to the west, but most of the well-built structures received only a few cracks. The dominant movement in Gaya was east-west; a monument in the compound of the Collector's Court was fractured horizontally by an east-west movement. The District Magistrate was definitely of the opinion that the first shocks were east-west and then changed to N.W.—S.E., and the Superintendent of the Hospital observed that the movements were east-west. There were five deaths (according to the *Statesman* 10, and over 50 injured) in Gaya and 34 in the district. For some time there was complete dislocation of the electric lighting, telegraph and telephone connections. The *Statesman* reported that the bed of the River Phalgu, which is ordinarily a dry bed of sand, gushed water and sand.

Bodh Gaya.—Six miles to the south of Gaya, was the scene of Buddha's great enlightenment under the shade of the Bodhi tree, the site of which can still be traced. The great Mahabodi temple, over 2,000 years old, is held in great veneration by Buddhists and Hindus alike. The copper ornament on a pinnacle of the temple bent over eastwards. The east-west walls were cracked and the roof moved 1½ inches to the east from the western wall. On the top floor a western wall fell towards the east and a roof coping fell east. The ornament at the top of the Bodh Mandir fell to the south; otherwise no damage was done to the temple. There were slight east-west cracks in some of the walls.

Santal Parganas.

Deoghar (24° 30′ : 86° 42′).—This is the headquarters of the subdivision of the same name. Deoghar is in the same zone which includes Dumka, the

headquarters of the district, the intensity being slightly higher than that of places to the north and south. Buildings were damaged by the usual wall cracks, over arches, doors, windows, etc., and roof beams pulled away slightly from the walls in some cases. The movements were dominantly east—west. The Subdivisional Officer was on tour in the subdivision but felt the movement to be east-west.

Nunihat (24° 29′ : 87° 08′).—This is a small village near the Lagwa hills on the borders of the Deoghar subdivision. The Inspection bungalow sustained a few slight cracks. An adjacent ornate bungalow was unaffected.

Hansdiha (24° 36′ : 87° 05′).—A few cracks were present in the bungalows.

Dumka—Naya Dumka (24° 16′ : 87° 15′).—This is the headquarters of the Santal Parganas. Dumka falls within a narrow zone of increased intensity, running roughly W.N.W.-E.S.E., and enclosed within the main isoseismal VII. The damage within this zone was sufficiently great as to mark it off from the rest of isoseismal VII. There was a general consensus of opinion that the first movements were east—west, later changing to north—south. One person related how he stood outside his house, a long structure aligned east-west and with a galvanised iron roof, and saw ripples six to eight inches high run along the roof! He was definite that they moved from east to west. Another person stated that he first heard a noise coming from the west. The Deputy Commissioner's bungalow was fractured by east-west movements. The roof had to be taken down. Other buildings, such as the Police Sergeant's bungalow, Mr. Dixie's house, St. Andrew's Church, Treasury and Sessions Court were somewhat cracked, some roof parapets collapsing. The Circuit House, Post Office and P. W. D. Office were unaffected. Movements at Dumka were mainly east—west.

Santal Parganas south of Bhagalpur.—South from Bhagalpur it was obvious that the damage diminished very rapidly indeed and the intensity was immediately reduced to VII, indeed, especially on the Gangetic flats, the intensity might almost be placed at VI. At Dumka, however, some moderately good bungalows were rather severely cracked and the intensity there was rather high. Similarly at Deoghar. It was difficult to compare Deoghar and Dumka as the buildings at Deoghar are rather older, more *kutcha* (or less *pucca*), but judging from the very slight cracking in the well-built station verandah, and comparing it with the absence of cracking in the best built structures at Dumka it may be said that at Deoghar the shock was a little more intense.

Comparing Rampur Hat with Deoghar, it was obvious that Rampur Hat got off lightly, notwithstanding that *kutcha-pucca* bungalows were more severely damaged. The P. W. D. bungalows were rather less damaged, and the station showed no sign of cracks—these may be compared with the better structures at Baidyanath Dham station.

A very noticeable feature throughout was that heavy P. W. D. structures showed worse damage than the light structures of the bazaars. This was obviously due to the heavy structures being unable to adjust themselves to the rapid movement of the foundations and was not necessarily due to bad foundations. Although the P. W. D. structures were cracked, they rarely collapsed, in contrast to the *kutcha-pucca* structures, which when once cracked frequently became ruined.

CHAPTER XXII.

ISOSEISMAL VII, SOUTH OF THE GANGES.

Shahabad district.

Arrah (25° 34′ : 84° 40′).—This town is the headquarters of the Shahabad district. The population in 1931 was 48,922. Buildings were damaged mainly by wall cracks and the occasional collapse of ornamental work. The Civil Court building and the Bar Library collapsed. In the bazaar several buildings, mainly old and of *kutcha-pucca* construction, collapsed and parts of other buildings fell. Six people were killed of which four were in one house. New buildings were undamaged. The Subdivisional Officer remarked that the movements were west-east, a view supported by others. In the S. D. O.'s bungalow bottles in an almirah facing east, on the western side of a room, fell east, on to the floor. Slight local subsidence of the ground was noticed.

Sasaram (24° 54′ : 84° 00′).—This town, a subdivisional headquarters in the Shahabad district, is situated two miles from the northern escarpment of the Kaimur hills. The town sustained very little damage. The courts, built of sandstone, were undamaged. Some of the official quarters were slightly cracked, including those of the Superintendent of Police and the Second Officer. Tiles came off the roof of the Munsiff's house. The S. D. O.'s quarters were badly cracked and some plaster fell. Three deaths took place in the bazaar owing to the collapse of a verandah.

Dehri-on-Son (24° 54′ : 84° 12′).—A few minor cracks appeared in the buildings.

Gaya district.

Jahanabad (25° 13′ : 85° 00′). This is the headquarters town of the subdivision of the same name and is situated at the confluence of the Monhar and Jamuna rivers. No houses collapsed in the town but about 50 per cent of the houses were damaged by cracks, mostly affecting the southern walls. The tendency was for east-west walls to show the most cracks.

Bela (25° 00′ : 85° 00′).—A small railway station about 15 miles south of Jahanabad. The Inspection bungalow and the railway station building were, slightly cracked.

Nawada (24° 54′ : 85° 36′).—This railway station on the South Bihar branch of the E. I. Railway from Kiul to Gaya, got off extremely lightly. The court building sustained some east-west cracks as also did the school building in which a few horizontal cracks appeared around the walls below the roof.

Monghyr district.

Sikandra (24° 58′ : 86° 02′).—This is a village in the Jamui subdivision, about 13 miles west of Jamui. The thana, a flat roofed *pucca* structure, built in 1927, was very slightly cracked, mainly by an east-west movement. In this respect Jhajha thana building, although better constructed, was worse damaged. In the

village, the worst damage was sustained by two-storey *pucca* buildings, some of which had to be rebuilt.

All deaths in the Jamui subdivision occurred west of Sikandra and on either side of the road to Nawada. Altogether six deaths were reported due to the fall of beams.

Kharagpur (25° 07′ : 86° 33′).—This village, in the Monghyr subdivision, is situated close to the eastern flank of the Kharagpur hills, and 25 miles south-east of Monghyr. In the bazaar area only the upper floors of two double-storey buildings were badly cracked. The Lee H. E. School, a fine *pucca* building, opened in 1932, showed no signs of any fracture. Cracks in other buildings were mainly due to east-west movements.

Mananpur.—At this railway station on the main line of the E. I. Railway, nine miles N.N.W. of Jamui, the buildings were cracked but not so badly as at Jhajha. All the station chimneys fell.

Jamui (24° 55′ : 86° 15′).—The headquarters of the subdivision of the same name, Jamui stands upon alluvium with hills in close proximity. Most of the buildings, such as the Station, Subdivisional Offices, Munsiff's Court, the Sub-Jail, were affected by cracks and fall of plaster, but not to any great extent.

Jhajha (24° 48′ : 86° 24′). At this important station on the E. I. Railway, situated in the south-east of the Jamui subdivision, the station buildings were badly cracked, much more so than at Jamui station, although both the stations were built about the same time. *Kutcha-pucca* buildings in the village were badly cracked and six of them fell, one being a three-storey structure. The roof of the eastern verandah of the thana collapsed because the steel beams fell out. A portion of the constables' barracks at Jhajha fell.

Bhagalpur district.

Bangaon (24° 59′ : 87° 00′).—This small village is about 17 miles due south of Bhagalpur, and was practically unaffected. The Dak bungalow sustained a few cracks in the east-west walls from east-west movement. The north-south walls were cracked.

Mandar Hill (24° 48′ : 87° 00′).—This village, situated about 30 miles south of the town of Bhagalpur, was very little damaged and there were but few cracks in the buildings. The north-south walls of the Inspection Bungalow sustained some vertical cracks.

Santal Parganas.

Rajmahal Hills (*Sahebganj-Rajmahal-Nalhati*).—South-east of Bhagalpur there was a rapid fall in intensity as the Rajmahal hills were entered. The tract is traversed by a meridional railway line and the well-built stations at regular intervals of four to six miles furnished reliable evidence of the incidence of the earthquake in the area.

At Sahebganj station the direction of the main movement was given by some observers as east-west, by others as definitely as north-south, the one series of tremors evidently following the other. Damage was confined to cracking of walls and ceilings of most of the old buildings at all stations along this line. Except at Sahebganj, where some private buildings (old and weak) and portions of the upper storeys of the Railway Institute and of the station fell, no other house

collapses were known. Rajmahal reported no damage beyond cracks in the railway station and in the corners of old houses. At Nalhati, though the vibrations were felt strongly, as perceived by the north-south rocking of a standing train on the platform and the shaking of the overbridge, aligned at right angles to it, no loose objects fell.

Birbhum district.

Rampur Hat (24° 10′ : 87° 47′).—This headquarters of the subdivision of the same name is situated on the western slope of an undulation, which commands a distant view of the hills of the Santal Parganas. The town has a locomotive depot of the E. I. R. Cracks developed in some of the buildings and the school was so badly damaged that it had to be demolished. The principal movements were apparently east-west, the room and verandah on the eastern side of the railway doctor's bungalow fell to the east, and the south-east corner of a three-storey tower on the south-west corner of a house fell to the east. The eastern rooms of a *kutcha-pucca* building fell to the east. The Station Master reported that the movements were definitely east-west. A large pad in his office slipped about six inches to the west.

Darjeeling district.

At Siliguri, a few miles south of the Himalayan foothills in North Bengal, there were no visible effects of the earthquake. Proceeding north along the Darjeeling Himalayan Railway the first signs were noticed at mile 2¼ above where a fissure in the embankment, two to three inches wide, ran N.20°W.—S.20°E., parallel to the rail line for about 200 yards. Another fissure was formed near Gulma, 5½ miles due north-east of Sukna along the rivulet of that name. It continued to spout water and white sand for some hours after the shock.

In the wide belt of hills between Darjeeling and the submontane tract around Sukna, no destructive effects were noticed in the buildings, or in the road and rail track, which remained open to traffic all through.

In the deep gorge of the Teesta valley, besides two large slips which occurred at mile 21 and some minor slips along the Teesta Valley road, no damage took place. No loss of life or property was reported at Kalimpong. The bridges (with one exception) were safe, including the recently completed single-span concrete bridge at mile 32, carrying the main road to Kalimpong and Sikkim. This fine structure admirably withstood the shock, although some reports stated that vibrations were felt strongly both in the direction of the long axis of the bridge (east-west) and transverse to it.

Jalpaiguri district.

Jalpaiguri.—Headquarters of the district of the same name and the Rajshahi division, this town reported no material damage to buildings, but a surface disturbance of the river bed, raking up some buried wood, was noticed.

CHAPTER XXIII.

ISOSEISMAL VI.

Champaran district.

Bagaha (27° 06′ : 84° 07′).—This large village in the Bettiah subdivision is situated on the eastern bank of the Great Gandak, 35 miles north-west of Bettiah, and was the end point of one of the re-levelling traverses made by the Survey of India subsequent to the earthquake. The village escaped damage during the earthquake, apart from a few cracks in the houses in the bazaar. Ornaments in Mr. Campbell Martin's house fell to the west and the western side of his house was slightly cracked.

Tribeni Ghat (27° 28′ : 83° 57′).—This is the name given to a *ghat* or passage over the Great Gandak at the extreme north-western corner of Champaran district, where the river first enters Indian territory. Not a crack was noticed in the headworks of the Tribeni canal, although the shock was felt badly enough. This is evident from the fact that Mr. Campbell Martin was thrown from a *machan* close to Tribeni Ghat while waiting for a tiger. The *shikaris* sat on the ground holding their stomachs. No sound was heard during the quake.

Burdwan district.

Asansol (23° 42′ : 87° 00′).—This town, the headquarters of a subdivision of the same name in the Burdwan district, is situated in the centre of the Raniganj coalfield. Population in 1931 was 28,888. The shock had little effect here but the office building of the Mines Board of Health, was reported to have been extensively cracked. A group of colliery managers who were together at the time saw ground waves moving from west to east, each perhaps six inches high and 12 feet from crest to crest. This was in addition to the usual vibratory motion. Cars on the road were swaying. Trees swayed and many people had a feeling of giddiness.

Murshidabad district.

Azimganj (24° 14′ : 88° 18′).—This town in the Lalbagh subdivision of Murshidabad district, is situated on the right bank of the Bhagirathi, 13 miles north of Berhampore. After the 1897 earthquake, it was reported to be in a state of ruin, but the town stood the present earthquake without any marked damage.

Berhampore (24° 06′ : 88° 18′).—Headquarters of Murshidabad district, Berhampore is situated on the river Bhagirathi. The damage to buildings was comparatively slight. The long lines of one or two-storey buildings (the old East India Co.'s barracks) constructed of massive masonry, and supported on rows of arches, withstood the shock very well. The government offices, aligned S.20°W., and the line of low arched barracks accommodating the Dak bungalow, the Church, the Post Office, etc., suffered from some minor cracks. The local Telegraph Office recorded the time of the earthquake as between 14·11 and 14·13 hours. The clock

of this office on a wall aligned W.20°N. did not stop, but the one in the adjacent Post Office room, fixed on a wall at right angles to the former stopped.

Murshidabad (24° 12′ : 88° 18′).—This town on the Bhagirathi in the Murshidabad district in Bengal, contains the palace of the Nawab Bahadur of Murshidabad, a lineal descendant of Mir Jafar Khan. It suffered greatly from the earthquake of 1897. During the present earthquake the palaces of the Nawab, a fine old, strongly built structure of brick and chunar sandstone masonry (1829), sustained some damage. The shorter, north-south, walls were cracked and the longer, east-west, walls, though intact, were displaced by three more or less parallel rents. These cracks were to a certain extent repetitions of those produced by the 1930 earthquake. The severest cracks tended to cluster round the north-west corner. At the Imambara, a new building opposite the Palace (and not so well constructed as the latter), enclosing an oblong quadrangle with east-west alignment, the south-facing parapet and balustrade collapsed. Three minarets, top-heavy structures supported on the rather weak balustrade, were hurled northwards and, breaking through the roof, crashed to the floor below. The clock tower in the quadrangle was standing, but its top portion was rent, accompanied by some fall of masonry.

Rajshahi district.

Rajshahi (*Rampur Boalia*). (24° 22′ : 88° 39′).—This district headquarters, situated on the north bank of the river Padma, was the easternmost station in Bengal visited by an officer of the Geological Survey of India after the earthquake. Time records were unreliable, none of the three clocks of the Postal Superintendent's office stopped. No noise was heard during the shock. The nature of the movements was said to be vibratory and undulatory as in a steamer. No objects fell. Parts of the walls of the Club House (108 years old) were damaged. The Mission House, also very old, had its portico pillars detached from the rafters of the roof and thrust six inches towards the south. In the town, portions of very old buildings came down but no noticeable effects were seen in *pucca* structures.

SECTION C.—ABSTRACTS OF REPLIES TO QUESTIONNAIRES.

(COMPILED BY A. M. N. GHOSH.)

CHAPTER XXIV.

ISOSEISMAL VII+

The nature of isoseismal VII+ has been described in Chapter II, where the linear arrangement of this belt of increased intensity was noted. As might be expected, it is less intense at its western end, Allahabad, than in Bihar, and, naturally, there is little difference between parts of this VII+ belt and those parts of VII close to isoseismal VIII. The point to be stressed is that there is an east-west belt of increased intensity within isoseismal VII with an area of somewhat lower intensity to the north of it. Although Bhabua, Sasaram and Dehri-on-Son are on this line the intensity of damage at those places was below that of the rest of this belt.

United Provinces.

ALLAHABAD DISTRICT.

Allahabad.

General, Allahabad.—The shock was strongly felt at Allahabad, where a number of houses were cracked, and some of them rather badly. The duration of the shock was more or less 180 seconds. A rumbling noise was heard by most people.

Collector.—He was travelling in a motor car and did not feel the shock. On making enquiries, however, he reported that a continuous shock with varying intensity was felt at Allahabad. A rumbling noise as if heavy traction engines were passing was heard during the shock. Some plaster fell in his bungalow which was cracked in many places. Many houses were cracked in the city.

District Judge.—Duration 180 seconds. He felt two severe shocks with a lull in between. Loose objects were thrown down and walls of buildings were cracked. A rumbling noise was heard before and during the shocks.

Nand Lal, Executive Engineer.—He felt several shocks and saw the stone cross over the Holy Trinity Church fall down. The stone finial over the dome of the clock tower in the Senate Hall was bent. The shock caused considerable damage to heavy two-storey buildings.

Superintendent, District Jail.—He felt one shock, which started rather strongly, then got weaker and became strong again before it died out. A rumbling noise was also heard.

Personal Assistant to the I. G., Police.—Three shocks were felt. All the walls of his bungalow were cracked. Some rooms in the I. G.'s office were badly cracked and had to be vacated.

A. C. Gupta, Accountant General, U. P.—He felt one shock and heard a noise as though an aeroplane passed overhead flying fairly low. The earthquake started with shaking of the desk and chair and then the whole building shook, the wooden ceiling showing the opening between each plank. The seats vibrated vertically and on the lawn the ground was undulating and earth ripples were noticed. The arch of the roof of the corridor on the first floor cracked in the centre--200 feet- bringing down the iron wedges fitted in old cracks. Walls cracked over arches and doorways and some bricks fell down. The jack-arched roofs of four rooms were badly damaged.

T. G. McGinn, Assistant Secretary to Government, U. P.—He felt one severe shock and heard a rumbling noise resembling that of a motor engine. Roofs of several rooms in the Secretariat block were damaged and debris fell. The walls of all the rooms were more or less cracked.

A. C. Holmes.—Dogs began to bark.

Postmaster.—Several pictures were thrown out of position. The ceiling of the main office hall and the stone staircases were cracked at several places.

J. M. David, Registrar, University of Allahabad.—Minor cracks appeared over several arches; the walls of the Zoological Department in the Muir Central College were slightly cracked. Two glasses of the Senate House Tower clock were broken and two stone finials on the top of the domes were bent.

Brjai Narain, Accountant, Excise Commissioner's Office.- Two shocks. The first lasted about 60 seconds and appeared to subside before the second shock of greater intensity started and lasted about 120 seconds. A sound as of an aeroplane was heard at the commencement and lasted during the shock. Houses shook and some of them were cracked.

J. P. Ghosh, Modern High School.—One continuous tremor accompanied by a sound like that of a high wind. Hanging objects swung east-west, walls of the school building sustained vertical cracks.

Garrison Engineer, Fort.—Felt one shock accompanied by a sound resembling that of a heavy lorry in motion. Ceiling fans swung 10°-15°. Several of the officers' quarters inside the Fort had to be evacuated as they were badly cracked and rendered unsafe pending repair. The church was rendered unsafe and had to be closed down for repair. In some of the buildings plaster fell and minor cracks occurred.

Lieut. Low, I.A.O.C., Fort.—Felt one long continuous shock. Rumbling noises were audible resembling stamping over a hollow floor or train going over a bridge. Masonry walls and roofs were cracked and some bricks and mortar fell in one room. Electric ceiling fans swung east-west. A small square tank full of water was observed to flow over to the east two or three times and the surface was still disturbed after about half an hour. A stationary motor car moved violently backwards and forwards and from side to side.

Executive Officer, Allahabad Cantonment.—Two shocks preceded by a noise like that of a motor car. Several buildings were cracked.

Naini.

Superintendent, Central Jail, Naini.—He felt one continuous shock. Buildings were cracked superficially in several places.

Mirzapur district.

Mirzapur.

Assistant Engineer.—He felt one shock during which a sound like that of a train was heard. Two houses were razed to the ground and the church steeple was broken. Some badly built houses were damaged.

Superintendent, District Jail.—Four to six shocks were felt. A rumbling noise was heard. Doors and windows rattled and hanging objects swung. A portion of the outer wall of the jail fell and cracks in several buildings of the jail and elsewhere were noticed.

Assistant Engineer, Special Division, Mirzapur Canals.—Six shocks of which the first was light and the third and the fifth very strong. During the shocks a buzzing noise as if half a dozen aeroplanes were flying very low was heard. Nearly every building in the station was cracked and a large number collapsed.

Station Master, E. I. R.—A severe shock accompanied by a rumbling noise. Blocks of plaster, bricks, etc., were thrown from walls and roofs. Some buildings in the railway colony were cracked, some badly and others to a lesser degree.

Medical Officer, Sadar Hospital.—Five shocks preceded by a rumbling noise like that of an aeroplane. Several houses collapsed and six persons were admitted into the hospital as a result of injury. It was difficult to remain standing and one felt giddy during the shocks.

Chunar.

The President, Settlement Notified Area.—He heard a noise similar to that of an aeroplane. Walls collapsed, joinings parted and severe cracks in the walls took place, two- and three-storey houses suffering the most. Some buildings were partially destroyed. Most of the wall-clocks stopped. Cracks took place in the ground on both banks of the Ganges. *Kutcha* buildings suffered the least.

P. W. Inspector, E. I. R.—One continuous shock accompanied by sound like the humming of bees. Doors rattled, telegraph wires danced and some of the buildings were cracked.

C. M. Ganguly, Medical Officer.—Two or three shocks preceded by a rumbling noise like that of an aeroplane and which continued during the shock. Some buildings fell down, a number partially collapsed and others were cracked.

Ahraura.

M. T. Khan, Chairman, Notified Area Committee.—A rumbling sound as of an aeroplane was heard during the shock, the direction of which was east—west. Loose objects fell towards the west. Small articles of about one pound in weight moved a few inches. North-south walls cracked from the plinth to the roof. Big and old houses fell and some were badly damaged.

J. N. Moitra, Medical Officer.—A rumbling noise as of a train going through a tunnel was heard during the shock. Doors and windows rattled, loose objects were thrown down and *pucca* houses collapsed.

Benares district.

Benares.

Dorothy Crosthwaite, Commissioner's House.—A continuous shock started suddenly and was accompanied by a sound resembling the roar of a heavy lorry.

Cracks, nearly all north-south, appeared in the walls. The parapet on the eastern porch running north-south was shaken loose. Other houses in the vicinity suffered from greater damage. A N. E.—S. W. movement of the ground was felt.

Executive Engineer.—The shock was continuous but intensified thrice, each time more than the previous one. A rumbling noise was heard throughout the quake. Walls of some buildings were cracked, parapets over roofs and also the roof of a building fell down.

S. K. Deva, Sub-Registrar, Machhlishahr.—He was at Benares at the time of the earthquake and felt a tremor followed by a smart shock, which increased in violence and lasted about 120 seconds. The shock was followed by a further tremor and suddenly stopped with a mild jerk. A humming noise like that of an aeroplane was heard throughout the shock, later it merged with the creaking sound of buildings which swayed like leaves of trees. The electric wires swung violently. The direction of swing of hanging objects was N. E.—S. W. approximately. Many buildings at Benares were cracked over the arches. Several two-storey houses collapsed. Three deaths were reported and some 25 persons injured by the fall of houses.

Major E. C. Cuthbert.—Every room of his bungalow, built in 1830, was cracked. A Morris car standing in low gear, oscillated about nine inches north-south lengthwise. There was a slight alteration of the floor level in the western rooms of the bungalow.

H. E. Jackson.—One shock of varying intensity. A sound as of a high wind and of heavy traffic was heard before and during the earth movement. Hanging objects swung east-west and light picture frames were moved. Walls of buildings were cracked and tiles of the roof of his bungalow moved.

Benares Cantonment.

S. S. Singh, Naib Tahsildar.—A sound resembling that of an aeroplane was heard during the shock. Hanging objects swung east-west.

Lieut.-Col. N. S. Taylor, Hyderabad Regiment.—Duration 180-240 seconds. Two shocks, preceded by a noise like that of a passing train. Doors and windows rattled, hanging objects swung north—south. Loose objects were thrown down towards south-east. His motor car standing north south swayed on its springs in an east-west direction. Col. Taylor standing in the compound felt a continuous series of short waves moving from west to east. Walls of many buildings were cracked and chimneys fell.

Kasi.

T. Cambridge, Executive Engineer in Charge, Dufferin Bridge, Kasi, E. I. R.—During the earthquake the Ganges swayed from side to side for a vertical height of two feet and in the two following days the water level rose by two inches, but four days later it was six inches lower.

Moghal Sarai.

P. B. Chatterjee, Bridge Foreman, Plant Depot, E. I. R.—He felt one shock which was accompanied by a rumbling noise as of a heavy lorry. Doors and windows rattled and hanging objects swung. Some houses were cracked.

BENARES STATE.

Chakia.

N. S. Anand, Collector, Benares State.—He was motoring at the time of the earthquake and noticed that suddenly the car was getting into a tremulous motion with a tendency to take to the eastern side of the road. On making enquiries afterwards he found that three separate shocks in quick succession were felt and a sound like that of a heavy lorry was heard before and during the shock. Hanging objects swung north-south. Loose objects were thrown towards the east. A number of stone walls fell and parts of *pucca* buildings collapsed, mud huts escaping. An east-west fissure in the ground, was three to four inches wide.

L. Chand, Tahsildar.—One shock lasting about 180 seconds. It was preceded by a rumbling noise like that of a heavy lorry coming from north-west. Hanging objects swung east-west and loose objects were thrown either east or west. The northern and eastern walls of the buildings were more cracked than others. Portions of some buildings collapsed. At Amra Patti Chaubisha village a small north-south fissure near a *nala* of the river Garai emitted water and sand. The fissure was two inches wide and water flowed for about four hours.

Latifshah.

P. Lal, Divisional Engineer, Latifshah (Chakia district), Benares State.—One shock for 180 seconds accompanied by a noise as of a motor car or aeroplane, coming from the north-west. Hanging objects swung north-south. Loose objects were thrown towards the east. The western and the northern walls of buildings were more cracked than others. Some buildings partially collapsed. Standing water in Latifshah reservoir was violently agitated and mud was brought up from the bottom.

Bihar.

GAYA DISTRICT.

Gaya.

Rai Bahadur C. C. Mukherji, O.B.E., Collector.—One shock for about 180 seconds. A rumbling noise was heard before and during the shock. The shock was severe enough to bring down many houses and almost every house was more or less damaged.

N. N. Maitra, S.D.O., Sadar (Gaya).—The clock of his *ijlas* stopped at 14·16 hours (I. S. T.). Duration 120-150 seconds. At first a rocking sensation was felt and in a second or two a rumbling noise as of heavy loaded lorries passing, or rolling of distant thunder, was heard. When he came out in the open the ground under his feet pulsated. A book rack three feet high, and full of books, fell down. Walls of many buildings were cracked. Four beams aligned east-west, on the portico of his house, moved two inches to the west. Tiles from the eastern and western roof slopes of the A. S. I.'s quarters were entirely shaken off, but very few from the northern and southern slopes. The ornamental domes on the top of the Collectorate building fell either due east or due west, that at the centre fell due south. Several balconies and walls collapsed.

G. Lorimer.—A slight tremor for 20-30 seconds intensified into a severe shock for 120 seconds and then gradually waned and died out within 20-30 seconds. A rumbling noise like that of thunder peels at a distance was heard throughout the

shocks. Iron poles for electric wires on the roof of the bungalow moved violently up and down with the wires. Pictures, glasses, tumblers, etc., were thrown down inside the bungalow. The walls of the bungalow although strengthened by iron plates and tie rods, were cracked. Mr. Lorimer felt an up and down and circular motion as if the ground under his feet was bubbling or boiling.

Santal Parganas.

Deoghar.

Indrasahib, Sub-Inspector of Police.—Duration 165 seconds one continuous up and down 'springing' motion. Before and during the shock a sound like that of an aeroplane combined with several motor trucks in motion was heard. Walls of many buildings were cracked and portions of some buildings collapsed.

Jasidih.

Bridge Foreman, Adjai Bridge.– An east-west ground movement for 180 seconds followed by an up and down movement for 120 seconds. A rumbling sound like that of low thunder was heard at the beginning and gradually died out towards the end of the quake. After the earthquake water in the Adjai river rose one foot nine inches, appeared to remain still for some time and then flowed down stream. Next morning the water was about three inches above normal. Cornices of buildings were cracked; water was spilled from a filled wash basin. Cracks appeared on newly made embankment and the old embankment settled slightly.

Madhupur.

S. Rai, Sub-Inspector of Police, Madhupur.—One continuous shock for 180 seconds. An unusual sound like that of a railway train was heard. The observer's seat moved. Walls were cracked. About ten houses were badly damaged and 600 houses were cracked within the *elaka* (jurisdiction).

Assistant Superintendent, Way and Works, E. I. R.—A preliminary tremor for 15 seconds was followed by a violent shock for 70 seconds during which the ground oscillated N.W.—S. E., with an estimated maximum amplitude of four inches and a frequency of 100 cycles per minute, which ended abruptly but was followed by tremors for another 100 seconds. A rumbling sound was heard for seven seconds at the beginning. A large number of buildings were cracked.

Dumka.

Sivanandan Prosad, Deputy Magistrate, Dumka. He was sitting in the Collectorate court room and felt the shock, which lasted about 180 seconds, at 14·15 hours (I. S. T.). Before and during the shock a rumbling noise was heard. The glass shutters and doors of the court room rattled and his table and chair were shaken. Hanging objects swung north-south and the ground and floor undulated. *Pucca* buildings were cracked and some were badly damaged.

ISOSEISMAL VII.

United Provinces.

Gorakhpur district.

Deoria.

Naib Tahsildar.—Three distinct shocks accompanied by a rumbling noise. Hanging objects swung north-south. Upper stories of some buildings came down. A small railway bridge near Salimpur and also the Tartipar bridge were damaged, the railway line near Nunkhar sank. The ground cracked in several places at Majhauli, where the Raj palace was seriously damaged.

R. N. Moitra, Head Master, King Edward Government High School.—One continuous shock accompanied by a rumbling noise like that of a huge tractor or steam roller passing N. E.—S. W. The school building sustained a few small cracks.

Tahsil Deoria.

Station Master.—One shock accompanied by a rumbling noise. Doors and windows rattled and some objects were thrown down. The front portion of the verandah of the railway station was damaged. Some tiles fell. Several houses were cracked. Another observer from the same places stated that a few fissures striking north-south ejected water and black sand.

Bhatni.

Station Master.—Two separate shocks preceded by a rumbling noise, as of a high wind or an aeroplane. Doors and windows rattled, hanging objects swung, loose objects were thrown down and several houses were damaged.

General.—Reports from other villages in the eastern and south-eastern portions of Gorakhpur district show that the shock felt there was sufficiently strong as to include the area in isoseismal VII.

Hata.

Tahsildar.—Movement east—west. Walls of several buildings were cracked. Three children were killed by the fall of walls in different villages in the *tahsil.* Several fissures were formed parallel to the river Gandak. The width of the fissures was from one to two feet and sand and water were discharged from them.

Azamgarh district.

General (Azamgarh district).—The shock appeared to have been widely felt over this district. Some people felt one continuous shock, others several. A rumbling noise preceded the shock and lasted throughout it. Most people agreed that the shock was felt in two directions namely, east-west and north-south, some observers were of the opinion that the shock travelled N. E.—S. W. A number of old buildings collapsed and *pucca* houses were damaged by partial collapse and cracking of the walls. The eastern part of the district near the Gogra river was the worst affected, In Ghosi tahsil cracking was general and severe, and four persons and some cattle were killed.

Maharajganj.

Siddiqu Ali.—One shock accompanied by a sound resembling that of a motor car. Doors and windows rattled, hanging objects swung east-west. Observer's seat moved. A few double storey houses were cracked.

Azamgarh.

K. P. Roy Chowdhury, Medical Officer.—The south-west corner of the Sadar Hospital including the entire verandah on the south and two rooms were badly cracked and partially destroyed.

Abdul Hussain, George High School.—One continuous shock preceded by a rumbling noise. Hanging objects swung north-south. Loose objects were thrown southwards. Roofs and walls of many houses were cracked and some of them collapsed. *Pucca* buildings and old mud huts were affected the most.

Thakur Bansh Raj Singh.—He felt four shocks, before and during which a rumbling noise like that of an aeroplane was heard. Hanging objects swung west-east. Observer's seat moved towards the east; loose objects were thrown towards the south-east. Of the various buildings that were damaged, their eastern portions and the east-west walls were the worst affected.

Y. Thiyuplus.—According to this observer walls aligned east-west and facing either north or south were more liable to be cracked than others. The shock was such that the objects were shaken in all directions but the main effects were north and south.

Ghosi.

Naib Tahsildar.—One shock accompanied by a rumbling noise. Walls of buildings were cracked and some old houses collapsed, killing three persons and two cattle. Hanging objects swung east-west.

Mau.

T. E. Paul.—A rumbling noise like that of an aeroplane was heard before the shock. Doors and windows rattled, hanging objects swung and some loose objects fell. The police station building and many houses in the town were damaged badly and some collapsed.

JAUNPUR DISTRICT.

Jaunpur.

Magistrate and Collector, Jaunpur district.—He felt one shock. A vase on a book case fell down. Several cracks appeared in his bungalow and a dozen bricks were dislodged from an arch of the verandah.

S. Wahid Aly, Tahsildar, Sadar.—He felt three shocks and heard a rumbling noise before and during the shocks, the direction of which was east-west. Bottles on an almirah fell both east and west. Walls of two and three-storey buildings were cracked.

R. K. Varma.—Heard a rumbling sound like that of an aeroplane. Hanging objects swung N. E.—S. W. Loose objects fell either north-east or south-west. Cracks occurred in buildings some of which had to be demolished. The shock lasted about 180 seconds.

Machhlishar.

Tahsildar.—Felt half a dozen shocks. A sound resembling that of a motor car preceded the tremor. The replies to the questionnaire are in conformity with isoseismal VII.

Head Master, Middle School.—Several shocks, accompanied by a sound like that of an aeroplane. Doors and windows rattled, hanging objects swung east-west. Loose objects were thrown down either east or west and a number of buildings were damaged.

Mariahu.

Tahsildar and Magistrate.— Two separate shocks, preceded by a rumbling noise. Two very old small houses in the bazar collapsed and the walls of a godown were cracked. Other buildings were slightly affected.

PARTABGARH DISTRICT.

Partabgarh.

Rai Bahadur S. B. Misra, Special Magistrate.—One continuous shock for 180 seconds, accompanied at first by a sound like the rattle of a lorry which changed to a sound like that of a railway train. Doors, windows, almirahs, etc., rattled, clothes hanging on pegs swung and clocks stopped. Direction of the shock was east-west. Brass idols and images on shelves fell down towards the east. Walls and roofs were cracked and *kutcha* walls and minarets of mosques fell down.

GHAZIPUR DISTRICT.

Ghazipur.

M. B. Dikshit, Magistrate and Collector, Ghazipur district.—He felt two shocks, one lasting about 30 seconds and the other, severer than the first, for 170 seconds. A sound like that of an aeroplane was heard before the shock. Hanging objects swung towards the south-east. Many walls were cracked and portion of an old house collapsed.

Khan Bahadur Asaf Zaman, Deputy Collector.--The verandah of a neighbouring house totally collapsed.

J. P. Sharma, Deputy Collector.—Three shocks preceded by a rumbling noise like that of a train. Walls of some buildings were cracked.

Tarighat.

Mohammad Zahoor.—Unusual sound like that of a motor car was heard. The station building, goods shed, waiting room, etc., were slightly cracked.

BALLIA DISTRICT.

Ballia.

Headmaster, Government High School.—One continuous shock preceded by a rumbling sound like that of thunder at a distance. The shock was feeble at first but became violent afterwards. Hanging objects swung east-west. Walls of old buildings were cracked and a few collapsed.

Mathura Prosad, Assistant Sub-Inspector of Police.—Objects were thrown towards the south. Some walls were cracked and the corners of the walls were thrown out.

General (Ballia town).—In this town some people felt one continuous shock and some three or four shocks. A rumbling noise like that of an aeroplane was heard before and during the shock. Doors and windows rattled, hanging objects swung east-west as well as north-south. Loose objects were thrown east, west and south. Walls of many buildings were cracked and a few houses collapsed. A chimney was thrown south.

MIRZAPUR DISTRICT.

Belwadah (24° 11′ : 82° 55′).

C. F. Wood, I. C. S.—One long continuous shock working up to a maximum and then dying away. A loud rumbling like that of a motor lorry was heard. Slight cracks were caused in various Forest bungalows and other buildings.

Pipri (24° 11′ : 83° 00′).

R. S. Bansad, E. A. C., Forests.—Three distinct shocks of which the second was most severe, and was accompanied by a rattling noise. Loose objects were seen to jump. Two walls of the Muirpur Rest House opened out at the joints and the tiled roof of a building at Kushalnagar had the tiles dislodged and they fell down.

Wyndhamgunj (24° 15′ : 83° 23′).

H. W. Tristram.—One continuous east-west shock of varying intensity was accompanied by a sound resembling that of an aeroplane. Loose objects were thrown down and walls of buildings were cracked. All the tiles were shaken off the roof of his bungalow.

Bihar.

CHAMPARAN DISTRICT.

Ramnagar.

M. P. Sinha.—Duration 180 seconds. Many shocks were felt and a noise like that of a motor underground was heard. Hanging objects swung east-west. Walls of buildings were cracked.

SARAN DISTRICT.

Siwan.

Rai Sahib R. Singh, Subdivisional Officer, Siwan.—He felt several severe shocks travelling N. W.- S. E. Duration 180 seconds. Objects fell either south or east. Fissures formed in the ground and many wells were choked with sand. Both *pucca* and *kutcha-pucca* structures were affected. At first he felt as if some one had pushed the chair on which he was sitting and later felt the trembling. The shock was strongest in the middle and he felt a swaying sensation as on a country boat. It was preceded by a sound like that of a motor car.

SHAHABAD DISTRICT.

The damage at Sasaram and Dehri-on-Son has been described in Chapter XXII.

Buxar.

R. L. Narasimham, S.D.O., Buxar.—One continuous shock lasting 180-240 seconds. Hanging objects swung north-south. A number of *pucca* and semi-*pucca* buildings were affected.

Buxar-Gajadharganj.

H. E. Beal.—His house moved backwards and forwards like a weaver's shuttle, in a N. E.—S. W. direction. He saw the cat run out of the house and it looked as if it was dancing on hot bricks. His house developed several shallow cracks.

Arrah.

R. A. E. Williams, Collector, Arrah.—Duration 180 seconds. One shock during which a rumbling noise as of a fast train was heard. Doors and windows rattled, loose objects fell down, his seat moved and walls of buildings were cracked. Several houses collapsed.

Ram Raksha Prasad, Deputy Collector.—Duration 210 seconds. One shock was felt. Movement was east-west, and up and down. Hanging objects swung west-east. Objects fell south as well as east. Bricks from roof copings fell to the east as well as to the north.

Bhabua.

M. Z. Khan, S.D.O., Bhabua.—Felt one shock for 180 seconds. Before and during the shock a rumbling sound as of an aeroplane was heard. Loose objects were thrown down and a number of buildings were cracked at Bhabua. In the subdivision about 400 buildings were cracked and some 190 collapsed.

PALAMAU DISTRICT.

General.—A small portion of the extreme north of this district falls within isoseismal VII. According to J. P. Sinha, Sub-Inspector of Police, the shock lasted 300 seconds at Untari, where almost all the walls and arches of *pucca* buildings were cracked. At Husainabad, according to S. W. Ahmad, Assistant Sub-Inspector of Police, buildings rocked like cradles and were cracked; here the shock is stated to have lasted 120 seconds. In both places a sound was heard. The Sub-Inspector of Police at Hariharganj thought that the shock was strongest in the middle when two pillars of the main thana and the thatched roof fell down.

GAYA DISTRICT.

Sone East Bank.

R. M. Watson.—A continuous swing for 300 seconds in a north-south direction. Doors rattled. Hanging objects swung. Loose objects were thrown down and his seat moved. Some buildings facing north and south were damaged by the roof moving backwards and forwards on the walls.

Nawada.

P. S. Prasad, Sub-Deputy Collector.—One continuous shock for 300 seconds. The swing was elliptical with major axis north-south. Duration of ground movement mostly north-south but sometimes east-west. Tiles from roof fell either north or south. East-west walls were worse cracked than north-south ones. Cracks

in river bed ran parallel to the banks of a dried up river running east-west and poured out water. Two or three storey *pucca* buildings were more affected than mud huts and light structures.

Monghyr district.

Jamui.

Inspector of Police.—Duration 180 seconds. Ground movement N.W.—S.E. Objects fell in all directions. *Pucca* buildings were mostly affected by cracks.

U. Biswas, Overseer.—One shock lasting about 150 seconds. Loose objects fell eastwards. Near the village of Kudhar fissures in the bed of the river were aligned N.W.—S.E. and were two inches wide.

Bhagalpur district.

Banka.

S. G. Jilani, Subdivisional Officer, Banka.—He was camping at Baunsi a few miles north-east of Banka and first felt a trembling, which was immediately followed by a tremendous noise like that of a fast moving train, about the same time a vigorous side to side movement ensued. The total duration of the earthquake was 150 seconds. His camp cot on which he was at the time lying moved. Almost all the *pucca* buildings in the subdivision were cracked. Some houses collapsed and three children were killed and several persons injured as a result. At places the ground cracked a little and ejected water and mud for a while.

P. K. Roy, Manager, Central Co-operative Union.—An up and down movement followed immediately by a to and fro movement. Total duration 180 seconds. A rumbling noise like thunder at a distance was heard 15 seconds before the shock. It came from north-west and passed off south-east, ending with the shock. One of the walls of his house cracked and gaped wide, throwing plaster. During the second movement the gaps closed and opened.

H. Prasad, Assistant Surgeon.—First shock up and down for 15 seconds, a second shock, having a sideways motion, immediately followed and lasted 225 seconds. Sound resembling that of a heavy lorry running fast on a hollow road was heard before and during the shocks. Some buildings partially collapsed ; water and mud came out of fissures in places.

N. Das Gupta, Sub-Deputy Magistrate.—An up and down movement followed by a north-south movement. The main shock lasted 180 seconds and tremors about 60 seconds. Plaster and masonry work on walls and turrets fell in many houses. A rafter running east-west was found to have completely turned upside down but fixed in its orignal position on the ceiling between the beams. Many *pucca* and semi-*pucca* brick houses with heavy roofs were badly affected but mud huts were mostly unaffected.

Santal Parganas.

Sarath.

M. Haque, Officer in Charge, Sarath Police Station.—Duration 150 seconds. One shock accompanied by a rumbling noise underground like that of an aeroplane. The shock was strong enough to make doors and windows rattle. Walls of pucca houses, the local mosque and the school building were cracked.

Rajmahal.

Maulavi S. K. Ahsan, Deputy Magistrate.—Three slight tremors in quick succession preceded the main shock. Duration 250-300 seconds. Sound like that of a motor car or aeroplane flying at a distance was heard from the west and passing east during the shock. He felt as if his chair was being raised by some one below it. Ground movement east-west. A "peepul" tree swayed east-west. Photo frames fell from the wall, buildings swayed and cracked. Officers' quarters, Dak bungalow, Sub-Jail and the local mosque were more or less affected.

Godda.

A. Prasad, S.D.O., Godda.—Severe shock for 120 seconds and slight tremor thereafter for another 120 seconds. Sound as of an aeroplane or heavy car or storm approaching was heard just before the shock. Almost all the buildings were more or less cracked and a few old *kutcha* buildings collapsed in the villages.

General (Godda Subdivision).—Reports from various places in the subdivision show that the shock was fairly strong and was preceded by rumblings which lasted throughout the quake. A widespread cracking of buildings took place and in many cases houses and walls collapsed. One man was reported to have been killed at Mahagama.

Bengal.

BIRBHUM DISTRICT.

Rampur Hat.

R. S. Krishnaswamy, Subdivisional Officer.—A roaring sound resembling that of an aeroplane was heard before and during the shock. Doors and windows rattled, hanging objects swung north—south, loose objects were thrown southwards. A few *pucca* buildings were damaged.

DINAJPUR DISTRICT.

Thakurgaon.

D. N. Saha, Subdivisional Officer.—A rumbling sound like that of a train at a distance was heard before, during and after the shock. Doors and windows rattled, hanging objects swung, the observer's seat moved and loose objects were thrown down. Walls of buildings were cracked.

G. N. Mukerjee, Sub Postmaster.—One shock beginning with a sound like that of 'rolling of the clouds'. Hanging objects swung N. W.—S. E. Several buildings were cracked.

JALPAIGURI DISTRICT.

Jalpaiguri.

A. N. Chakraburty, Meteorological Observer.—Two distinct shocks preceded by a rumbling noise as of an aeroplane. Doors and windows rattled, hanging objects swung and loose objects were thrown down. Some of the buildings were badly cracked but none collapsed. Arched roof cracked in places and bricks fell down.

Darjeeling district.

Hathighisa.

Manager, Atal Tea Estate.—Rapid continuous oscillation in increasing intensity. The replies to questionnaire are in conformity with isoseismal VII.

Bagdogra.

Manager, Bagdogra Tea Estate.—One severe and one slight shock. The shock was strong enough to crack the walls of buildings and to cause greater damage.

Sukna.

S. D. Chatterjee, Sukna Tea Estate.—Three shocks preceded by a sound like that of a motor car, and which lasted to the end Hanging objects swung and loose objects fell. Semi-*pucca* brick walls were cracked. Fissures in the ground were six inches wide.

Phagu.

Manager, Mission Hill Tea Estate.—Two shocks, doors and windows rattled and hanging objects swung. Factory walls of stone cracked and fell down.

Teesta Bridge Bazar.

J. S. Lama.—A rumbling noise like that of an aeroplane preceded the shock. Everybody felt the shock which caused doors and windows to rattle and cracked the walls of many houses, some of which were damaged rather badly. Fissures half an inch wide were aligned north-south. The river swelled about nine inches from the normal level.

Kalimpong.

N. Bose.—One shock with a slight rumbling noise. Doors and windows rattled, hanging objects swung and the observer's seat moved. Many walls were slightly cracked and a few badly damaged.

W. A. S. Lewis, Subdivisional Officer.—He was at Thode Khas Mahal Block (27° 07′ : 88° 49′) and felt one continuous shock. A rumbling noise was heard and was intensified by fall of rocks and earth down the precipices. He felt it difficult to stand without support. Landslides occurred. One semi-*pucca* mud and stone building was slightly cracked.

Khamdung.

R. S. Prosad.—One strong shock for 120 seconds. Slight cracks occurred in the walls of houses.

Sikkim.

Pandam, Rangpo P. O.

K. Pradhan.—Two or three strong shocks for 240 seconds. Loud reports like those of cannon shot were heard two or three days before and one just before the shock. People ran out of their houses, doors and windows rattled, and loose objects fell down. Practically all walls made of stone and mud were cracked. Two storey buildings were badly damaged and some of them had to be pulled down. At some places the ground was fissured.

Rhenok.

Rai Bahadur T. D. S. Pradhan.—One shock for 165 seconds. Doors and windows rattled, hanging objects swung, the observer's seat moved and loose objects were thrown down. Walls of buildings were cracked and the flow of water in many springs increased after the shock.

Namgong Elaka, Rinchenpung P. O.

A. L. D. Lama.—Several shocks for about 300 seconds. Sound like an explosion was heard in the distant hills to the south-west after the shock. Walls of many buildings were cracked and six dwelling houses of *pucca* walls were totally destroyed.

Song, Singtam P. O.

Song Kazi.—Three shocks for 180 seconds, preceded by a sound like that of an explosion caused by dynamite. Doors rattled, loose objects were thrown and the observer's seat moved. Stone walls of several houses were cracked and three or four houses partially collapsed.

Pakhyong.

G. Singh.—Three shocks for 120 seconds, preceded by a rumbling noise like that of a motor car. Doors and windows rattled, hanging objects swung and all the bottles in an almirah fell down. Most of the stone walls of houses were cracked.

Gangtok.

Assistant Engineer, P. W. D.—One heavy shock for about 180 seconds at about 2·25 p. m. followed by numerous slight shocks. Doors and windows rattled and ceiling and flooring heavily cracked. Hanging objects swung and crockery lying on shelves in the store godown and in certain Dak bungalows in Sikkim dropped and broke into pieces. Cracks, some superficial and some serious, appeared in the walls of almost all the stone masonry buildings and Dak bungalows in Sikkim. Walls of many buildings in Gangtok cracked heavily. The walls bulged in some cases and some of them had to be pulled down. The Dak bungalows at Namchi and Dentam with out-houses collapsed to the plinth. Two of the chimneys of the Residency building and a portion of the walls of its houses, of the S. T. N. High School and the Palace collapsed.

Samdong.

Rai Bahadur Lobzang Chhoden.—Reporting from Lingmo, in the Teesta valley near Samdong bridge, he stated that he felt three shocks for about 180 seconds. Rattling sounds were heard of stones falling, with a landslip on the left bank of the river. Loose objects fell and many houses were cracked. Three or four small buildings collapsed, as also the Mani Lhakhang temple at Lingmo. In some place the ground was fissured.

Turuk.

Moti Chand Prodhan.—Several shocks for 180 seconds, but the main shock was felt for ten seconds. The replies are in conformity to isoseismal VII; at several places cracks formed in the ground.

Ringan.

Margaret L. Doig.—Several shocks. The preliminary tremors were followed by severe ones and shook the Mission House violently. A large part of the front wall of the upper storey collapsed outwards. A sound as of muffled thunder was heard continually and it receded and seemed to roll away northwards up the Talung valley. All the walls of the Mission House were cracked but no glass panes were damaged.

TIBET.

Yatung.

Sub-Assistant Surgeon and Meteorological Observer.—The observer was indoors talking to a friend when he felt several violent tremors at 2·18 p.m. Doors and windows rattled, hanging objects swung and some loose objects were thrown down. His seat was pushed. Walls of three buildings collapsed and several walls were cracked.

CHAPTER XXV.

ISOSEISMAL VI.

Within this isoseismal a large number of small places suffered less severe damage, the intensity of which would correspond to V (G. S. I. Scale). Lack of space, however, prevents enumeration of these places.

United Provinces.

MUTTRA DISTRICT.

Muttra.

Brahmdutta, Tahsildar.—Two shocks were felt. According to this observer the shock in Muttra district was continuous and sufficiently strong to disturb a person at rest. A rumbling noise was heard before and during the shock. Doors and windows rattled, hanging objects swung north-south, but nothing was thrown down. Walls of buildings were slightly cracked.

H. C. Agarwal, S.D.O., P.W.D., Muttra.—One shock which lasted about 120 seconds and was preceded by a rumbling noise. Doors and windows rattled, hanging objects swung and the observer's seat moved.

ALIGARH DISTRICT.

Aligarh.

M. J. Khan, Physics Department, Muslim University.—Two shocks felt by persons at rest. Doors, windows and loose objects rattled and hanging objects swung. Some loose objects fell down and a few old walls were cracked.

ETAH DISTRICT.

Etah.

The Collector, Etah dist.—One continuous shock with imperceptible breaks. Doors, windows, etc., rattled. Hanging objects swung east-west. Shock was strong enough to shake a *pucca* building.

SHAHJAHANPUR DISTRICT.

Shahjahanpur.

R. Husamkha, Chairman, Municipal Board.—He felt three shocks. Doors and windows rattled and hanging objects swung north-south.

Superintendent of Manufacture.—The main shock lasted about 45 seconds and was succeeded by slight quivers for 120 seconds. Hanging objects swung east-west and several silver cups fell off the mantelpiece. Walls of some buildings were cracked.

Rup Chandra, Munsiff.—He felt two shocks. Hanging objects swung east-west. Some loose objects fell. Doors and windows rattled.

Executive Officer, Municipal Board.—Three heavy and two slight shocks for 270 seconds. Felt by every one. Hanging objects swung east-west. Walls of some buildings were cracked.

Rosa.

P. B. Annelt, R.S.F., Rosa, E.I.R.—One shock accompanied by a rumbling noise like that of a heavy train. Doors and windows rattled and hanging objects swung. Shed building and flood-light pillars swayed from side to side.

KHERI DISTRICT.

Kheri.

Kheri, general.—At Kheri some people felt a north-south movement and some an east-west. Most people reported that hanging objects swung north-south and loose objects fell northwards. One observer reported some six or seven shocks and a very feeble sound was heard after the main shock. Some people felt an up and down movement.

S. A. Hassain.—He felt one shock which was preceded by a sound like that of a motor car. Hanging objects swung east-west. Some of the buildings were slightly cracked.

AGRA DISTRICT.

Agra.

M. H. Kuraishi, Superintendent, Archæological Survey of India.—A few old buildings were cracked.

C. W. Lacey, Executive Engineer. He felt two separate shocks, the second one being of shorter duration (10-15 seconds) and occurring 60 seconds after the first shock. Doors and windows rattled, hanging objects moved and the shocks were felt by most people.

B. K. Mukerji, Income Tax Officer.—He felt two shocks for about three seconds. Ceiling fans swung east-west.

Superintendent, Taj and other Govt. gardens.—He felt one shock which was felt by persons at rest. Hanging objects swung and doors and windows rattled.

Firozabad.

M. Singh, Executive Officer, Municipal Board.—He felt two shocks which were preceded by a humming sound. The shocks were felt by persons at rest.

Tundla.

Railway Staff, E.I.R.—Duration of the shock 200 seconds. Doors and windows rattled, electric lights were swinging and some loose objects were thrown down. Several railway bungalows were cracked.

MAINPURI DISTRICT.

Mainpuri.

Hariharlal Bhargam.—A rumbling sound was heard during the shock. Doors and windows rattled and hanging objects swung east-west.

FARRUKHABAD DISTRICT.

Farrukhabad.

C. L. Wallace, District Magistrate.—Violent tremors for 90 seconds with side to side motion were followed by up and down motion. A dull rumbling noise like that of a train approaching a station preceded the tremors. Doors and windows rattled, hanging objects swung and the observer's seat moved.

Tahsildar, Sadar.—He felt one continuous shock, before which a rumbling noise like that caused by an aeroplane was heard. Walls of some buildings were cracked.

Fatehgarh.

Lt.-Col. F. R. Cosent, 10/7th Rajput Regiment.—One shock lasting about 90 seconds, accompanied by a slight rumbling noise. Doors of his bungalow rattled violently, the thatched roof cracked and some plaster fell from the cornice. The observer noticed waves passing under his feet in the compound and across the thatched roof of the bungalow. The direction of movement was west-east.

G. A. Dhawaley and B. B. P. Singh, Deputy Magistrates.—One shock preceded by a sound like that of a motor car. Doors and windows rattled, hanging objects swung and their seats moved.

M. M. Seth, Headmaster, Govt. High School.—Two shocks. A rumbling noise like that of a motor car was heard. Doors rattled, hanging objects swung, his seat moved, and a time-piece was thrown down towards the south. A tall palm tree in the compound swayed north-south.

Kanauj.

B. Mitra Narain, Secretary, Municipal Board.—One preliminary shock for 60 seconds followed, after an interval of five seconds, by the main shock which lasted 120 seconds. Some mild rumbling noise was heard after the first shock and the sound resembled that of an aeroplane. Doors and windows rattled, hanging objects swung and his seat moved. One or two old walls were slightly cracked.

HARDOI DISTRICT.

Shahabad.

Munsif, Shahabad.—He felt three shocks of which the first was mild and the two others appreciably severe. Loose objects rattled, as also doors and windows. Hanging objects swung east-west. Some buildings were cracked.

Hardoi.

Assistant Prosecuting Inspector.—He felt three shocks. Hanging objects swung east-west. Objects fell either east or west.

R. C. Good, A.S.W., E.I.R.—Three shocks. Doors and windows rattled, hanging objects swung, his seat moved. Some buildings in the city sustained minor

Bilgram.

Tahsildar.—A few walls of some buildings were cracked.

ETAWAH DISTRICT.

Etawah.

W. W. Finlay, Collector.—He felt a series of tremors, which caused trees to shake in an east-west direction. The tremors lasted about 120-180 seconds.

S. N. Saksena, Naib Tahsildar.—One continuous shock. Doors and windows rattled. Roofs and walls of some buildings were cracked.

CAWNPORE DISTRICT.

Cawnpore.

Deputy Superintendent of Telegraphs.—Two continuous shocks for 240 seconds. An unusual sound was heard before and during the shock. Doors and windows rattled, hanging objects swung, his seat moved and loose objects were thrown down. Some houses cracked and collapsed. Mosque pillars were cracked.

City Tahsildar.—One continuous shock accompanied by a rumbling noise. Hanging objects swung N.W.—S.E. A few houses fell.

Tahsildar.—Three shocks preceded by a rumbling noise which continued till the end. Hanging objects swung north-south. Some walls were cracked.

Sub-Overseer of Unao.—He was at Cawnpore at the time of the earthquake and felt three shocks. A sound like that of a railway train was heard during the shocks. Hanging objects swung north-south. Trunks fell down in a shop and several buildings collapsed.

JALAUN DISTRICT.

Kalpi.

Tahsildar.—One shock accompanied by a rumbling noise like that of an aeroplane. Walls and roofs of some buildings were cracked. The peak (dome?) of the Lanka Tower of Kalpi fell down.

Orai.

Tahsildar.—One shock preceded by an unusual noise like that of an aeroplane and which lasted till the end. Hanging objects swung N.E.—S. W. Three mud huts collapsed and walls of a few old and lofty buildings were cracked.

JHANSI DISTRICT.

Jhansi.

The Collector, Jhansi dist.—He felt one shock but heard no noise. Doors and windows rattled and slight cracks appeared in some of the buildings.

S. Temple.—Two shocks with an interval of 30 seconds. Total duration 120 seconds. During the shock a rumbling noise like that of a train or very heavy vehicle passing was heard. Doors and windows rattled, hanging objects swung and the bamboo sunshades of the verandah vibrated violently up and down.

Another observer from Jhansi felt one continuous shock getting worse and then subsiding. Duration 180 seconds. A continuous rumbling noise was heard.

HAMIRPUR DISTRICT.

Mahoba.

Executive Engineer, Ken Canal Division.—One shock preceded by a rumbling sound like that of a moving train. Some buildings had slight surface cracks.

Tahsildar.—Two shocks at an interval of 90 seconds. At the time of the second shock a sound like that of a motor engine at distance was heard. Walls of a number of houses in the town were cracked.

L. Singh.—A continuous shock for 210 seconds, accompanied by a droning sound as of an aeroplane. Hanging objects swung north-south.

Hamirpur.

Naib Tahsildar.—Duration 180 seconds. One continuous but not very strong shock was felt during which a rumbling noise like that of a motor car or an aeroplane was heard. Doors and windows rattled, hanging objects swung, loose objects were thrown down and the observer's seat moved. Tiles from roofs of houses were thrown down and walls of buildings were cracked to a slight extent.

Mandaha.

Naib Tahsildar.—Walls of many buildings were cracked.

SITAPUR DISTRICT.

Sitapur.

Naib Tahsildar.—Four shocks were felt. Doors and windows rattled and hanging objects swung east-west. Some loose objects were thrown down.

LUCKNOW DISTRICT.

Lucknow.

Bishop of Lucknow.—He felt one continuous shock over 180 seconds. Doors and windows rattled and pictures fell at all angles. Walls of some buildings were cracked. Roofs of two quarters in Allahabad Fort fell in and the cross fell from the spire of the Holy Trinity Church.

M. Victor.—He felt a strong shock which lasted over 120 seconds and was accompanied by a rumbling noise. Many objects in the four-storey house were thrown down and all the doors and windows rattled. The building swayed in a north-south direction along its length and portions of the building were cracked.

A. S. Athar Ali Shah, Naib Tahsildar.—Three or four shocks accompanied by a rumbling noise. Doors and windows rattled, hanging objects swung and loose objects were thrown down. Walls of some buildings were cracked.

S. K. Mendis, Signal Workshop, E. I. R.—One shock accompanied by a sound as if oil were boiling. Doors and windows rattled and his seat moved. Some buildings were cracked.

BARABANKI DISTRICT.

Fatehpur.

Naib Tahsildar.—Three shocks of which the middle one was the strongest. A humming noise like that of an aeroplane was heard during the shock. Hanging objects swung north-south and loose objects were thrown down towards the north.

Nawabganj.

Daya Shankar, Tahsildar, Sadar.—One shock, accompanied by a rumbling noise like that of a motor car. The shock was felt both up and down and sideways. Loose objects were thrown down from west to east. Walls of building were cracked and tiles thrown off.

Haidargarh.

Tahsildar.—Hanging objects swung north-south and loose objects were thrown southwards. One shock was felt during which a rumbling noise like that of an aeroplane was heard. Walls of some buildings were cracked.

UNAO DISTRICT.

Unao.

Vice Chairman, Municipal Board.—Three shocks lasting about 180 seconds. A rumbling noise like that of a railway train was heard before and during the shock. Doors and windows rattled, hanging objects swung north-south. The observer's seat was moved and loose objects were thrown towards the north. Walls of several houses and domes of several temples and mosques either fell or were cracked.

Executive Engineer's Office Staff.—A rumbling sound like that of a motor car in motion was heard. The shock was fairly strong. Old cracks opened and were widened.

Headmaster, Government High School.—Hanging objects swung east-west and walls of buildings were slightly cracked.

A. N. Vyas.—A strong shock accompanied by a sound like that of a motor car coming from the north-west.

P. S. Varma, Medical Officer, Dist. Hospital.—One shock for 180 seconds during which a sound like that of a railway train was heard. The observer's seat moved towards the east. Several buildings were cracked.

RAE BARELI DISTRICT.

Rae Bareli.

Civil Surgeon.—Felt three big shocks and five tremors before and after the main shocks which lasted about 200 seconds. A rumbling noise like that of an aeroplane was heard before the shock. The shock was strong enough to crack the walls of buildings.

H. D. Ghosh, Headmaster, Government High School.—Two shocks lasting about 250 seconds. Loose objects, doors and windows rattled. Water in a pool shook in a N. E. S. W. direction. Cracks appeared on the arches over several doors of the building.

District and Sessions Judge.—Two shocks of great intensity. Sounds resembling that of an aeroplane preceded the shock. Walls of several buildings and roof arches were cracked.

Amir Chand, District Board Engineer.—About four or five shocks. An unusual sound like that of a "grinding mill" was heard. Doors and windows rattled, hanging objects swung east-west. Some walls were slightly cracked.

Kali Prosad, Headmaster, Hindu High School.—He heard a rumbling noise and felt an east-west movement.

A. S. Hussain, Deputy Collector.—One continuous shock during which a sound resembling that of a goods train was heard. Doors and windows rattled. Both *kutcha* and *pucca* walls were cracked and some fell.

B. Upadhyaya, Headmaster, Kisan School.—Three shocks of which the second was the strongest. Hanging objects first swung west-east and then north-south. A rumbling noise was heard before and during the shock.

P. D. Pandy.—Three shocks preceded by a rumbling noise. Hanging objects swung east-west. East and west walls were cracked.

Adwatpur.

J. N. Mitra, S.D.O., P.W.D., Unao District Sadar Canal.—He was at Adwatpur I. H. and felt one continuous shock, the intensity lessening for an interval during its duration. A motor car rocked to and fro in a north-south direction. Doors and windows rattled violently. The floor of the verandah, made of stone slabs, quivered violently.

FATHEPUR DISTRICT.

Fatehpur.

M. Hussain.—A rumbling noise like that of an aeroplane was heard. Doors and windows rattled, hanging objects swung and his seat moved. Walls of a few large buildings like that of the kutchery were cracked slightly.

Permanent Way Inspector, E.I.R.—One continuous shock. Loose objects were thrown down and some buildings sustained hairbreadth cracks.

BANDA DISTRICT.

Banda.

Chairman, Municipal Board.—Two shocks were felt during which sounds like that of an aeroplane were heard. Doors and windows rattled. Some cracks occurred over the arches of the Jumma Mosque.

Tahsildar.—Three shocks accompanied by a rumbling noise like that of a railway train. Portions of some buildings collapsed and many buildings were cracked.

Divisional Forest Officer.—One shock preceded by a rumbling noise like that of an aeroplane. Doors and windows rattled and hanging objects swung east-west. Small loose objects were thrown down. Plaster fell from joints of walls and ceilings.

Lakshmi Chand, Assistant Engineer, P.W.D.—One strong but continuous shock for over 180 seconds. Some loose tiles fell off the roof and walls of some buildings were very slightly cracked.

Gaurihar.

Overseer, P.W.D.—One heavy and two light shocks. Sounds like a motor running at a distance were heard before and during the shocks. Tiles fell from the roof. Hanging objects swung north-south. The Jagir Jail was cracked.

Manikpur.

P. W. Inspector, G.I.P.R.—One continuous shock for 120 seconds. A rumbling noise was heard during the shock. Hanging objects swung north-south. Doors rattled and the observer's seat moved.

Bargarh.

Station Master, G.I.P.R.—One moderate but continuous shock lasting 180 seconds. It was preceded by a 'thundering' noise. Hanging objects swung N.E.—S.W. and loose objects fell north-east. Walls of the 3rd class waiting room sustained a few cracks.

ALLAHABAD DISTRICT.

Jasra.

Station Master, G.I.P.R.—One shock for 150 seconds. Hanging objects swung north-south loose objects were thrown either north or south. All the walls of a waiting room were cracked and the side walls slightly pushed.

BAHRAICH DISTRICT.

Bahraich.

D. Singh, Executive Officer, Municipal Board.—A gentle shock followed by a strong rocking movement and accompanied by a rumbling noise. Loose objects fell east. North-south walls were cracked, some projections on the second storey of houses and tower decorations fell.

P. Pant, Civil Surgeon.—Sound like that of a railway train was heard during the shock. A photo hanging on the wall fell down. Walls and arches of some buildings were cracked.

Subordinate Judge.—One continuous shock which grew in intensity. Duration 180 seconds. Hanging objects swung east-west. Walls of some buildings were cracked.

Syed Hussain, S.O., Kotwali—Three shocks accompanied by a noise like that of an aeroplane. Hanging objects swung east-west. Some buildings were slightly cracked. The upper storey of a very old building had to be pulled down, and some brick work fell from the roof of the *chauk* well.

B. Nath, District Medical Officer.—Two shocks for 180 seconds during which an unusual sound was heard. Hanging objects swung east-west, doors and windows rattled, his seat moved and loose objects were thrown either east or west.

B. Parsad, Deputy Collector.—Duration 210 seconds. He felt two strong shocks. A rattling noise like that of a bullock cart going very fast was followed by a rumbling noise like that of a motor car, and at one time the sound was like that of thunder when it seemed as if great objects were rolling and making a sound which appeared to be passing from east to west. Clods of earth fell from the walls and the roof. Hanging objects swung east-west and loose objects were thrown eastwards.

Motipur.

K. Nath, Range Forest Officer.—Four separate shocks, the first and the last were mild but the middle ones were fairly strong. Doors and windows rattled.

GONDA DISTRICT.

Gonda.

A. N. Kapur, Medical Officer.—Two shocks during which a sound like that of a train running underground was heard. Hanging objects swung east-west and walls of some buildings were cracked.

P. Sinha.—A mild tremor increasing in intensity and lasting 240 seconds. It was accompanied by a sound like that of a motor car. He saw the upper storey of his house swaying east-west. Doors and windows rattled. Walls and roofs of many buildings in the town were cracked. Parapets, cornices, and portions of walls of several houses fell down. Tiles came off the roof.

Superintendent, District Jail.—One shock consisting of several tremors during which a rumbling noise was heard. Hanging objects swung east-west and loose

objects were thrown in these directions. Walls of buildings were cracked and plaster fell.

Subordinate Judge.—One continuous shock during which a rumbling noise like that of an aeroplane was heard. Hanging objects swung east-west. An empty bottle fell to the east. Several cracks took place in the Sub Judge's office and Munsif's court and some other buildings.

B. K. Singh, Income Tax Office.—One severe shock followed by minor tremors. Both the arches of the portico of the Income Tax Office were cracked.

Bankey Bihari Lal, Sanitary Inspector.—Two shocks accompanied by a rumbling noise. Hanging objects swung east-west. Many buildings were cracked and some of them were rather badly damaged *e.g.* the Police Office, a Deputy Collector's bungalow, Municipal School and Civil courts.

Mohammad Umar, Veterinary Surgeon.—Three shocks. Movement north-south. The walls of the compounder's quarters were cracked at several places and bricks fell.

Rangi.

C. S. Cartman, District Opium Officer.—He felt a continuous vibration in a north-south direction. The shock approached from east and passed westwards. A sound resembling that of a strong wind accompanied by a patter of rain was heard. The shock was fairly sharp, hanging objects swung north-south and walls of buildings were slightly cracked.

Janakhpur.

Divisional Forest Officer.—A tremor followed by one violent shock. Water splashed from a bucket in a N. N. W.—S. S. E. direction. Walls of some buildings were cracked.

Balrampur.

A. A. Waugh, Special Manager, Balrampur State.—He was in the jungle (27°-46′ : 82°13′), three miles south of the foothills of Nepal, sitting on the ground when the shock took place. At first he felt a vertical shaking, after about 30 seconds this changed to a lateral movement in which the ground appeared to "swim". Water in puddles had a marked tendency to pile up on the eastern side of the puddles, though swinging from side to side. A rumbling noise lasting about 30 seconds was heard after the first vertical shock.

FYZABAD DISTRICT.

Ajodhya.

Medical Officer, Sri Ram Hospital.—Several shocks preceded by a rumbling noise. Hanging objects swung east-west. Doors and windows rattled and some walls were cracked.

Fyzabad.

District Judge.—One continuous shock preceded by a rumbling noise. Doors and windows rattled, hanging objects swung and walls of some buildings were cracked.

Postmaster.—One continuous shock for about 300 seconds. A rumbling noise as of a motor lorry was heard during the shock. Hanging objects swung north-south and loose objects were thrown either north or south.

Executive Engineer.—One shock accompanied by a rattling noise as of a heavy lorry. The rattle increased in intensity for 120 seconds and then died. A motor car standing north-south swayed violently as if shaken sideways by hand. Walls of buildings were cracked.

On the whole the buildings in Fyzabad were more cracked than those at Gorakhpur. Only a few buildings in either place were seriously damaged, although most of the buildings had many minor cracks.

I. I. Shaw, Secretary, Museum Committee.—A loud noise like that of a huge motor preceded the shock. The museum building swayed to and fro.

Head Clerk, Court of Wards.—Three shocks accompanied by sound as of an aeroplane. Many buildings were cracked.

Tahsildar.—A sound similar to that of an aeroplane was heard during the shock. Loose objects were thrown in different directions. 80 per cent. of the masonry buildings and girdered roofs were cracked. A few of them collapsed.

Major F. E. B. Manning, I.M.S.—One continuous shock accompanied by a rumbling noise as of a railway train. His seat moved. Some buildings were cracked.

M. O. Sexton, Sub-divisional Officer, Fyzabad.—One continuous shock preceded by a rumbling noise as of a heavy laden lorry. Ceiling fans swung east-west. Loose objects were thrown towards the east. Cracks appeared over arches and on partition walls. The top layer of tiles on the roof of the R. C. Church slipped off bringing a part of the masonry away with it.

Superintendent, District Jail.—One continuous shock preceded by a rumbling noise which lasted during the shock. Hanging objects swung east-west. Some of the arches were cracked.

Agent, Imperial Bank of India.—Two shocks during which a rattling noise like that of heavy lorry was heard. Hanging objects swung east-west. Bags of coins, weighing 2 maunds 5 seers each, fell down from stacks on all sides in the bank's strong room. Practically all *pucca* houses of every description were more or less cracked.

Fyzabad Cantonment.

Major A. Rea, 4/7th Rajput Rifles.—One shock preceded by sounds as of very heavy lorries laden with empty tins. Doors and windows rattled, hanging objects swung N.E.—S.W. and loose objects were thrown down in all directions with a tendency towards the north-east. Some walls were cracked.

Tanda.

P. Singh, Medical Officer.—Three shocks preceded by a rumbling noise, which continued during the shock. Doors rattled, hanging objects swung east-west. Old buildings were rather badly cracked.

Jalalpur.

Medical Officer.—Movement was north-south. Hanging objects swung in this direction and loose objects fell either north or south. Walls of some buildings were cracked.

Sultanpur District.

Musafirkhana.

Tahsildar.—One continuous shock for 200 seconds during which a rumbling noise as of a railway train was heard. Doors and windows rattled, hanging objects swung east-west and the observer's seat moved. The shock was strong enough to crack the walls of several buildings and some mosques.

Medical Officer.—Duration 180 seconds. One continuous shock during which a rumbling noise as of a railway train was heard. Water in a pot fell.

Sultanpur.

Executive Officer, Municipal Board.—One continuous shock with a sound like that of a motor car. Hanging objects swung east-west. Several *pucca* houses were cracked.

Tahsildar, Sadar.—He heard a low rumbling noise preceding the shock like that of a heavy lorry or goods train approaching slowly. The noise preceded the shock. Hanging objects swung north-south. Loose objects fell either north or south. Generally the corners of *pucca* buildings opened to a slight extent.

Headmaster, Govt. High School.—One continuous shock with an up and down and side to side movement. Hanging objects swung east-west and loose objects were thrown either east or west. Walls and roofs of *pucca* buildings were cracked.

C. P. Tandon, Medical Officer, District Hospital.—Two definite shocks accompanied by a deep rumbling noise passing underground. Fine cracks developed over the walls of the hospital building. Some toys were thrown down.

K. Kaul, Sub-Judge.—Felt three or four shocks. The roofs of the verandah of the Civil Court building and two of the portico arches were cracked at several places.

R. Sankar, Chairman, Municipal Board.—He felt one continuous shock accompanied by a noise like that of a motor car. Hanging objects swung east-west. Cracks appeared in several buildings.

S. P. Sahi, Chairman, District Board.—Rolling, pulsation and grinding under the feet were felt. At first the sound was like that of the engine of a big lorry, later a grinding sound was heard. Water in a big fountain was thrown out. Doors rattled vigorously. Tie rods below arches rattled, chandeliers swung north-south. Walls and arches of buildings were cracked.

Amethi.

Tahsildar.—Duration 100 seconds. One continuous shock before and during which a rumbling noise as of an aeroplane was heard. Hanging objects swung east-west. Some buildings were cracked.

Kadirpur.

Tahsildar.—Two shocks lasting about 300 seconds. Doors rattled, hanging objects swung east-west and loose objects fell either east or west. Walls of buildings cracked a little.

BASTI DISTRICT.

Bansi.

Tahsildar.—Several shocks of which the middle ones were the severest. Direction of movement was east-west; 15 per cent. of the houses and most of the north-south walls were cracked.

Basti.

S. A. Ali, Tahsildar.—Duration 150 seconds. Three continuous shocks, the last having a circular component. The shocks were preceded by a rumbling noise as of an aeroplane, or a train running at a high speed. Hanging objects swung N.E.—S.W. Buildings were cracked mostly from top to bottom.

Domariaganj.

A. Ahmad, Tahsildar.—Duration 150 seconds. Two to three shocks in quick succession. Rumbling noise was heard before and during the shocks. Hanging objects swung east-west. Horizontal cracks appeared on the walls of buildings.

GORAKHPUR DISTRICT.

Maharajganj.

G. S. Lal.—Trees swayed east-west. Walls of several buildings were cracked

Siswa Bazar.

N. G. Bose.—One shock accompanied by a rumbling noise. Loose objects rattled. Ink pots fell on the table. Hanging objects swung.

Gorakhpur.

J. R. Izat, Office of the Agent, B. & N. W. R.—Total duration of the shock was 180 seconds. First a strong tremor with undulations about three per second which decreased and then suddenly increased and become hard and jarring before it died. A sound like that of a train or heavy lorry was heard during the shock. Many bungalows were cracked and the top of one chimney was thrown down. Overhead fans swung violently (3-4 ft.) to and fro, in an east-west direction.

G. Shanker, Naib Tahsildar.—One continuous shock accompanied by a rumbling noise. Many houses were cracked and some of them collapsed.

A. W. White.—One shock with a rumbling noise as of a storm approaching. Doors and windows rattled, hanging objects swung and a few buildings were cracked.

A. C. Pelly, Principal, St. Andrew's College.—The shock was accompanied by a rumbling noise like that of a heavy steam roller. Doors and windows rattled, hanging objects swung east-west. Bottles in the laboratories and one almirah fell. Buildings were cracked.

B. & N. W. Railway Staff.—Duration 120-192 seconds. One continuous shock before and during which a rumbling noise as of a motor lorry or aeroplane was heard. Doors and windows rattled, hanging objects swung and loose objects fell. Walls of many buildings were cracked. A large steel structure swayed east-west over four inches.

G. Lal, Headmaster, Govt. High School.—Flower vases weighing two pounds each were thrown down from a height of seven feet. Walls and arches cracked horizontally.

Tamkuhi Road.

A. B. Khan, Station Master.—Goods shed building and station were badly cracked. Several houses in the village were badly damaged and some of them partially collapsed.

Rajputana.

BHARATPUR STATE.

Bharatpur.

C. P. Hancock, President, Council of State, Bharatpur.—Several shocks lasting 120-180 seconds and observed by all. Time 14.15 hours. An underground rumbling was heard besides rattling of doors. Hanging objects swung east-west. Walls of a few buildings were cracked.

KARAULI STATE.

Karauli.

Rao Bahadur S. N. Sharma, Dewan.—Time 14.15 hours. Two separate shocks for 300 seconds, the second being intense. A rumbling and rattling sound like that of a passing aeroplane preceded the shocks, which were widely felt. Doors and windows rattled, hanging objects swung east-west. The observer's seat was shaken and walls of buildings were cracked. A few old buildings collapsed.

DHOLPUR STATE.

Dholpur.

K. Tewari, Financial Secretary.—Three distinct shocks, of which one was very strong, in addition to many minor tremors, all lasting 300 seconds. A rumbling noise like that of an aeroplane was heard during the shocks. Doors and windows rattled, hanging objects swung east-west, the observer's seat was moved and walls of a few buildings were cracked.

Narain Singh, Assistant Revenue Secretary.—Three or four shocks for 240 seconds, felt by persons at rest. Loose objects rattled, hanging objects swung east-west. Some clay fell from walls and the joints of some walls were cracked.

G. K. Goswami, Assistant Private Secretary.—One shock for 120 seconds accompanied by a rumbling noise like that of a road steam roller. Hanging objects swung east-west and walls of buildings were cracked.

Nahar Singh, Customs Officer.—One strong shock for 120 seconds accompanied by a hissing sound under the feet. Cracks were seen in certain buildings and some old buildings collapsed.

Capt. J. B. Clutterbuck, Assist. Executive Engineer, Chambal Bridge.—Duration 120-180 seconds. Hanging objects swung north-south. The Senior Bridge Inspector, who was standing on one of the piers of the Chambal Bridge stated that the free ends of the girders moved half an inch longitudinally from north-south.

E. A. Thorpe and A. N. Thorpe.—Three shocks or tremors for 180 seconds preceded by a rumbling like that of a heavy motor lorry. The second observer was awakened from sleep. Doors rattled and hanging objects swung N.E.—S.W. A clock on a sideboard fell down and some plaster cornice fell.

Bundi State.

Bundi.

Executive Engineer.—One continuous shock at 14.15 hours lasting 120 seconds. A sound resembling a 'grinding mill' was heard during the shock. Persons at rest felt the shock, doors rattled, the observer's seat moved and some loose objects were thrown down.

Kotah State.

Kotah.

Rai Bahadur Pandit B. Nath, Member, Mahakma Khas, Kotah State.—Two or three strong shocks lasting 120-180 seconds. In some places a rumbling noise like that of a motor car about to start was heard before the shocks were felt; no such sound was heard at other places. Persons at rest felt the shocks, doors and windows rattled, hanging objects swung and the observer's seat moved. Loose objects were thrown down in some places and superficial cracks appeared in several buildings.

Baran.

Station Master.- One continuous shock for 120 seconds. The station roof rattled and wagons standing in the yard moved to and fro with the shock.

Salpura.

Station Master.—A slight shock for one second.

Jhalawar State.

Jhalrapatan.

B. L. Sharma. -Time 14.18 hours. One shock for 120 seconds. It was felt by persons at rest, doors and windows rattled and the observer's seat moved.

Central India.

Baoni State.

Baoni-Kadaura.

M. A. Khan, Dewan, Baoni State.—Three shocks for 30 seconds and trembling for several minutes. A sound like a running engine was heard during the shocks. Doors and windows rattled, hanging objects swung east-west. The observer's seat moved and loose objects were thrown down. There were many cracks in the hospital building.

Beri State.

Beri.

D. P. Johary, Kamdar of Beri.—Two shocks at an interval of two or three minutes. Total duration of the shocks was 150 seconds. A rattling sound was heard just before the shocks. Persons at rest felt the shocks, doors rattled and hanging objects swung east-west. Some loose objects were thrown westwards. A few old masonry walls were cracked and a few *kutcha* houses collapsed.

SAMTHAR STATE.

Samthar.

The Dewan, Samthar State.—Two or three mild shocks in continuation for 240 seconds. During the shocks a sound as of an aeroplane was heard. Doors and windows rattled and hanging objects swung east-west.

DATIA STATE.

Datia.

Khan Bahadur Kazi Sir A. Ahmad, C.I.E., O.B.E., I.S.O., Dewan, Datia State.—One continuous tremor for 270 seconds during which a rumbling sound was heard underground. Doors and windows rattled and hanging objects swung. His chair was shaken and cracks appeared in several buildings.

BANKA PAHARI JAGIR (STATE).

Banka Pahari.

J. Lal.—Two shocks for 180 seconds. During the shocks a sound was heard which resembled that of several motor vehicles. Doors and windows rattled and hanging objects swung east-west. The observer's seat moved, tiles fell from roofs and birds flew. Plaster cracks appeared in houses and weak *kutcha* structures were damaged.

BIHAT JAGIR (STATE).

Kohnia.

Brij Kishore, Kamdar, Bihat Jagir.—Two shocks for 240 seconds. An unusual sound like that of a motor car or an aeroplane was heard before and during the shocks. Doors rattled, hanging objects swung east-west, loose objects were thrown either east or west and the observer's seat moved in the same direction. Walls of some buildings were cracked.

SARILA STATE.

Sarila.

P. Narain, Dewan, Sarila State.—Two shocks for 180 seconds. A sound like that of the running of machines was heard during the shock. Doors and windows rattled, hanging objects swung east-west and the observer's seat moved. Slight cracks appeared in dilapidated buildings.

JIGNI STATE.

Jigni.

The Kamdar of Jigni.—One severe shock for 180 seconds. It was preceded by a sound like that of an aeroplane or the approach of a motor car. Doors and windows rattled, hanging objects swung north-south, the observer's seat was shaken towards the south and loose objects fell in the same direction. The palace walls were cracked and two houses and the office building collapsed.

DHURWAI STATE.

Dhurwai.

The Kamdar of Dhurwai.—One shock for 180 seconds. It was preceded by a sound like that of a train. Persons at rest felt the shock. Loo e objects fell westwards. Tiles fell from the roof.

TOHRI FATEHPUR JAGIR (STATE).

Tohri Fatehpur.

C. B. Singh.—Two shocks for 120 seconds. Unusual sounds resembling "drum beats" were heard before the shocks, which were felt by all. Hanging objects swung N. E.—S. W. Walls of some buildings were cracked.

CHARKHARI STATE.

Charkhari.

R. P. Tiwari, Chief Revenue Officer.—One continuous shock for 180 seconds. A sound like the approach of a goods train was heard from the beginning to the end of the shock, which was slight at the beginning and end and strongest in the middle. Doors and windows rattled, hanging objects swung and the observer's seat was shaken. Loose objects were thrown down in all directions and walls of old *pucca* buildings were cracked.

PAHRA JAGIR (STATE).

Pahra.

B. Lal, Kamdar, Pahra Jagir.—One shock for 60 seconds. A sound like that of a lorry was heard during the shock. Hanging objects swung east-west and the observer's seat moved. Tiles fell from the roofs of many houses and loose objects were thrown westwards.

TARAON JAGIR.

Chitrakot.

Assistant Station Master, G. I. P. R.—Several shocks, commencing with a rumbling noise as of a motor car. The first shock was mild and was followed by stronger shocks. The station doors rattled and ceiling lamps swung violently west-east. The ground shook in the same direction.

PALDEO JAGIR (STATE).

Nayagaon.

B. Prosad, Kamdar.—One shock for 300 seconds. A rumbling noise like that of a heavy machine rolling underground was heard during the shock. Hanging objects swung east-west and loose objects were thrown down towards west. The observer's seat was shaken. Walls of some buildings were otackod.

BARAUNDA STATE.

Baraunda.

Dewan, Baraunda State.—One shock for 30 seconds. Three minutes before the perceptible shock a loud noise as of an aeroplane flying overhead was heard

and it continued for about a minute. Most persons felt the shock. Loose objects rattled and tiles fell from the roofs of houses.

ALIPURA STATE.

Alipura.

Rattan Singh.—An earthquake of rather severe intensity lasting about 180 seconds was followed by a mild tremor for 120 seconds. The shock travelled east-west and was preceded by a noise like that of a motor car also travelling in the same direction. Doors and windows rattled, hanging objects swung east-west and the observer's seat was shaken. Some loose objects were thrown westwards and old walls were slightly cracked.

GARRAULI STATE.

The Kamdar of Garrauli.—Three shocks lasting 180 seconds. The middle shock was the strongest and lasted longer than the two others. Before and during the shocks sounds like the rattling of a heavy lorry driven at full speed or the roaring of an aeroplane were heard. Trees swayed, persons lying on beds were jerked up, doors rattled and buildings trembled.

BIJAWAR STATE.

Nowgong.

S. N. Srivastava, Meteorological Observer.—Three successive and separate shocks for 240 seconds. A rumbling noise was heard during the shocks. Doors rattled, hanging objects swung, the observer's seat was shaken, loose objects fell and walls of some buildings were cracked.

Bijawar.

The Dewan, Bijawar State.—Two shocks for 180 seconds. A rumbling noise like that of a car was heard during the shocks. Doors and windows rattled, hanging objects swung N. E.—S. W., the observer's seat moved and loose objects were thrown towards the north. Certain buildings were slightly cracked.

ORCHHA STATE.

Tikamgarh.

M. Paul, Dewan, Orchha State.—One continuous shock for 180 seconds. An underground rumbling noise at the beginning changed into a noise like a motor car engine. Most persons felt the shock, doors and windows rattled, hanging objects swung and the observer's seat moved.

PANNA STATE.

Panna.

V. Chand, Superintendent of Police.—One shock for 180 seconds accompanied by a rumbling noise. Persons at rest felt the shock, doors and windows rattled, hanging objects swung north-south, the observer's seat moved and some loose objects were thrown northwards. Some buildings were slightly cracked.

Kothi State.

Kothi.

The Dewan, Kothi State.—Duration 210 seconds. One shock preceded by a sound that continued for a few seconds, and resembled that of several cars in motion during the shock. Hanging objects swung N. W.—S. E., the observer's seat moved and some loose objects were thrown towards the south-east. Walls of some of the double storey buildings made of stone and lime were cracked.

Nagod State.

Nagod.

L. S. B. Singh, President, State Council.—One continuous shock for 180 seconds. A rumbling noise like that of a motor car preceded the shock which was felt by most persons. Doors and windows rattled, hanging objects swung north-south, the observer's seat moved and loose objects were thrown down southwards. Small cracks appeared in several buildings.

Ajaigarh State.

J. K. Mathur, Acting Dewan, Ajaigarh State.—One shock for 300 seconds. A rumbling noise as of a motor car was heard before and during the shock. Other replies to the questionnaire are in conformity with isoseismal VI.

Jaso State.

Jaso.

Lachman Singh.—Two shocks for 120 seconds. A sound as of a motor bus was heard before the shock. Doors rattled, hanging objects swung east-west, the observer's seat was shaken and some loose objects fell towards the west Some buildings were cracked.

Maihar State.

Maihar.

Rai Sahib N. N. Majumdar, Dewan, Maihar State.—Two or three shocks of different intensity within 180 seconds. A deep rumbling sound as of distant thunder or a train on a distant bridge was heard before and during the shocks. Doors and windows rattled, hanging objects swung N. E.—S. W. and the observer's seat moved in the same direction.

Station Master.—One continuous shock for 50 seconds at 14·17 hours. A rumbling like the noise of a motor car was heard during the shock, hanging objects swung and the observer's seat moved. A wall of a signalman's quarters was cracked.

Rewah State.

Satna.

Time Keeper, G. I. P. Railway Workshop.—One shock for 160 seconds during which a 'gurgling' sound, as if a stove were burning under foot, was heard. The ground moved east-west and all the fittings and fixtures in the rooms of the workshop were swinging.

Rewah.

Superintendent, Medical Department.—A single continuous shock for 300 seconds. Doors and windows rattled, hanging electric lights swung N. E.—S. W. A stone wall in the jail was slightly cracked.

MUHAMMADGARH STATE.

Muhammadgarh.

The Kamdar, Muhammadgarh.—One shock for 76 seconds. It was preceded by a sound like that of a fast running motor car. Loose objects rattled, the seat of the observer moved as on a rolling ship. Some of the buildings were cracked.

KORWAI STATE.

Korwai.

A. R. Khan.—One slight shock for 120 seconds causing doors and windows to rattle. Hanging objects swung and the observer's seat moved. Walls of several buildings were cracked.

Gwalior State.

Gwalior.

Sunder Lal, Assistant Surgeon, Residency.—Three continuous shocks one after another and lasting about 300 seconds. Before and during the shocks a rumbling noise as of an aeroplane was heard. Doors rattled, hanging objects swung north-south, the observer's seat moved and loose objects were thrown towards the south. Walls of buildings were cracked.

Khamiadhana.

Administrator, Khamiadhana Estate.—One continuous shock for 180 seconds. Before and during the shock sounds like an aeroplane were heard. Persons at rest felt the shock and doors rattled. Hanging objects swung north-south, the observer's seat was shaken and loose objects fell south. Walls of some buildings were cracked.

ISAGARH DISTRICT (GWALIOR).

Guna.

Station Master, Guna, G. I. P. R.—One shock for 180 seconds. It was felt by persons at rest, doors and windows rattled and loose objects were thrown either east or west.

Tumkeri.

P. W. Inspector, G. I. P. R.—One shock for 150 seconds. Most persons felt the shock, doors and windows rattled and the observer's seat moved. Loose objects were thrown either east or west. Walls of the P. W. Inspector's bungalow were badly cracked.

BHILSA DISTRICT (GWALIOR).

Sumer.

Dattatraya Narayan.—One continuous tremor felt by persons at rest, doors and windows rattled. Walls of some buildings were cracked and the walls of "A" cabin were damaged and about four feet of two walls near the roof fell to the west.

Central Provinces.

SAUGOR DISTRICT.

Bina.

Resident Engineer, G. I. P. R.—One continuous shock for 180 seconds. Doors and windows rattled, walls of several blocks were cracked and two gabled walls on the east and west of a block collapsed.

R. P. McCready.—One continuous tremor for 180 seconds, felt by persons at rest. Some walls were cracked and both the side walls of a bungalow fell inwards about five feet from the top, near the roof.

Saugor.

S. H. Y. Oulsnam.—One shock felt by persons at rest. Doors and windows rattled and some tall buildings were cracked.

Assistant Executive Engineer.—Minor cracks on the upper portions of the walls of several government buildings. Some heavy key-stones of the arches of the verandah became loosened in the Civil Court buildings and settled about an inch or two downwards.

Tahsildar.—Two shocks. Some walls were cracked in places.

H. E. Schmidt, Overseer, P. W. D.—One shock preceded by a rumbling noise like that of carts on a road. Hanging objects swung; some buildings were cracked.

Resident Engineer, G. I. P. R.—One shock for 180 seconds. Doors and windows rattled and hanging objects swung.

DAMOH DISTRICT.

Damoh.

Tahsildar.—Duration 165 seconds. Three shocks, of which the first was the strongest. A sound as of an incoming train was heard before the shocks. Doors and windows rattled, hanging objects swung N. E.—S. W. and walls of some buildings were cracked.

V. I. Mertough, P. W. Inspector, G. I. P. R.—One continuous circular motion lasting about 120 seconds. A rumbling noise was heard before the shock as if a train were passing over a bridge. Doors and windows rattled and curtain beads swung N. E.—S. W.

JUBBULPORE DISTRICT.

Katni.

P. W. Inspector, G. I. P. R.—One continuous shock felt by persons at rest. Doors and windows rattled, hanging objects swung north-south and the observer's seat moved.

Bihar.

PALAMAU DISTRICT.

General (Palamau district).—Reports from various police stations all over the district show that one continuous shock lasting 120-300 seconds was felt. The sound, comparable to the noise caused by an aeroplane or a motor car,

was audible in some cases before and in all cases during and in one case after the shock. The shock was felt by almost everybody, doors and windows rattled, tiles from roof and loose objects fell and large and old buildings were slightly cracked. In one or two instances *kutcha* walls collapsed.

Ranka.

P. Singh, Sub-Inspector of Police.—One continuous shock for 300 seconds. Before and during the shock an unusual sound like that of an aeroplane or a motor was heard. Hanging objects swung, doors rattled, the observer's seat moved and big buildings were damaged.

Daltonganj.

Superintendent of Police, Palamau.—A mild shock gradually becoming intense and very severe. Duration 240 seconds. A rattling sound was heard at the beginning of the shock and it changed into a rumbling sound later. The ground shook badly making it difficult for one to remain steady. Walls and roof of the bungalow were badly cracked.

At Singra, five miles north of Daltonganj, the earth on the banks of the rivers Gursote and Amanat were cracked. Water shot out up to five feet in height at the junction of the Koel and the Amanat.

M. A. Ashruff, Meteorological Observer.—One shock for 300 seconds from 14·11 to 14·16 hours. Unusual sounds like those of an aeroplane or motor car were heard during the shock, which was felt by most persons. Doors and windows rattled, hanging objects swung and loose objects fell. Walls of almost all the buildings were cracked.

A. K. Bose, Forest Ranger.—Five shocks for 360 seconds, during which a sound resembling that caused by a railway engine passing at a distance was heard.

Latehar.

G. S. Singh, Sub-Inspector of Police.—One continuous shock for 180 seconds, accompanied by a sound as of an aeroplane. The shock was felt by persons at rest, doors and windows rattled, hanging objects swung and walls of buildings were cracked. The observer's seat was shaken.

HAZARIBAGH DISTRICT.

General (Hazaribagh district).—Reports from the police stations in various parts of this districts show that the earthquake was widely felt in Hazaribagh district and was accompanied by a rumbling noise comparable to that made by an aeroplane or motor car or railway train. Cracking of houses was general, the Parasnath temple and the dak bungalow at Parasnath were damaged. At many places tiles fell from roofs of houses.

Kodarma.

S. S. Prasad, Range Officer.—One shock for 120 seconds. It was preceded by a sound like the approach of a motor car. Doors rattled, hanging objects swung and the observer's seat moved. Walls of several buildings were cracked.

Sub-Inspector of Police.—One shock for 240-300 seconds. A rumbling noise as of an aeroplane was heard. Doors rattled, loose objects fell and about 75 buildings were cracked.

Barhi.

Sub-Inspector of Police.—Two shocks for 240 seconds. A rumbling noise as of an aeroplane was heard. Doors rattled and the observer's seat moved. Walls of buildings were slightly cracked.

Partabpur.

Sub-Inspector of Police.—The shock lasted 180 seconds. The replies to the questionnaire are in accord with isoseismal VI.

Chatra.

Sub-Inspector of Police.—One shock for 220 seconds accompanied by a rumbling noise as of an aeroplane. The replies are in accord with isoseismal VI.

Hazaribagh.

Subdivisional Officer, Sadar.—One continuous shock for 180 seconds during which a humming noise was heard. Walls of many buildings were cracked.

C. Choudhury, Meteorological Observer.—Time 14·11 (I. S. T.). Several jerks in quick succession were felt over a period of 240 seconds. Some of the later jerks were quicker and more severe, and five minutes after the main shocks a slight shock was felt. A muffled, rumbling noise like that of a heavy motor van passing at a distance was heard. The earthquake was felt by most persons, doors and windows rattled and the observer's seat moved. Walls of buildings were cracked, the turret on the north-western corner of the local college building collapsed, that on the north-eastern corner swayed but did not crack and the steeple of the Church was cracked.

Sub-Inspector of Police, Sadar.—Two or three shocks for 180 seconds. A rumbling noise as of an aeroplane was heard. Doors and windows rattled, hanging objects swung and loose objects were thrown down. All the houses were slightly cracked.

Giridih.

Subdivisional Officer, Giridih.—Several continuous shocks for 180 seconds. A rumbling noise as of a railway train was heard. Doors and windows rattled, hanging objects swung and the observer's seat moved. Walls of buildings were cracked.

S. N. Haider, Deputy Magistrate.—One continuous shock for 180 seconds during which a rumbling noise as of a motor car was heard. A strong up and down movement, shaking the ground under his feet and his table, was felt. Electric fans and ceiling lamps swung. Doors rattled and walls of buildings were cracked.

H. Banerjie, Giridih Bar Association.—Three or four shock for 150 seconds accompanied by a rumbling noise as of a heavy motor bus. Portions of some buildings and tin sheds collapsed.

Jhumri Telaiya.

C. C. Augier.—Time 14·15 (I. S. T.). Duration 480 seconds with intermissions, there being four or five intervals between the shocks during the last 240 seconds. He was sitting at his office table facing north-west and heard a hollow rumbling noise, increasing in intensity, coming from W. 20° N. and passing in the opposite direction. Two or three seconds later his chair was pushed upwards and for the

first 30 or 40 seconds large but not severe waves appeared. The tremor then increased in severity and the waves were reduced to a foot from crest to crest. The shocks were most intense during the first four minutes. Roof of a shed built of *sal* wood poles, bamboos and country tiles vibrated with great speed.

RANCHI DISTRICT.

Bagechampa.

M. Khan, Southern Forest Range Officer, Netarhat P. O., Marmai, Ranchi.—In the jungle, sitting, he felt one shock for 180 seconds. Before and during the shock a rumbling noise, like that of a train in motion, was heard. He almost fell when he stood up. *Nuriah* (country) tiles from a sloping roof fell and several walls of buildings in the locality were cracked and some collapsed.

Ranchi.

E. Horsfield, Deputy Commissioner, Ranchi district.—Two shocks separated by a short interval. Duration 240 seconds. The vibration was accompanied by a noise as of an approaching heavy lorry or train. Persons at rest felt the shocks, and doors and windows rattled. Walls of buildings were cracked.

Charu Chandra Roy, Meteorological Observer.—Time 14·12-14·15 hours. Duration 180 seconds. Two perceptible shocks accompanied by a rumbling noise as of an aeroplane. Doors and windows rattled, hanging objects swung, loose objects were thrown down and his seat moved. The office buildings of the Executive Engineer were cracked and greater damage was done to some of the old masonry buildings of the town. Several buildings at Kanke Mental Hospital were cracked and the P. W. D. Divisional office and an old tiled building at Dorandah were cracked. Eye-witnesses stated that in some cases the cracks opened as much as two inches during the shocks. Corners and junctions of most of the walls were cracked and plaster fell down in these buildings.

N. G. Dunbar, Superintending Engineer, Chota Nagpur Circle.—He was reclining on a couch and felt one shock for 180 seconds. At first there was a rumbling sound for a second and then the couch started to tremble and all the doors and windows rattled violently for 180 seconds, the maximum intensity of the rattling was during the first 90 seconds. His wife was aroused from sleep. Objects hanging on the verandah wall swayed about and two silver cups on pedestals were knocked down. All the pictures on the north and the south walls ended up with a decided slope downwards towards the east, those on the east and the west walls remained as they were before. He felt a decided east-west movement. There were two slight cracks in his *pucca* house and practically every *pucca* house in Ranchi got slight cracks. Some of the *kutcha-pucca* buildings sustained larger cracks.

Immediately before the shock a strong wind was blowing from the north-west. During the shock and for about 15 minutes afterwards there was a dead calm; the strong wind then recommenced blowing.

MANBHUM DISTRICT.

Dhanbad.

C. Forrester, Vice-Principal, Indian School of Mines.—Time 14·15-14·19 hours. Duration 240 seconds. A sound as of rushing wind was heard immediately prior to the shock: during the main shock and immediately thereafter a deep-toned

rumbling noise was heard. The shock was felt by persons at rest and caused bottles and various objects on shelves to overbalance and fall to the floor. A pendulum and ceiling fans swung in a direction east-west approximately. All the old cracks in the school building were widened and new cracks appeared in walls running east-west. There was evidence on the roof of slight compressional forces acting east-west, producing north-south cracks with slight overriding.

S. C. Ghosh, Head Assistant, Additional D. C.'s Office.—Time 14·15 hours. Duration 95 seconds. One shock of moderate intensity at commencement and then a continuous shock for about 90 seconds of same intensity which diminished later. A rumbling sound as of a heavy lorry was heard during the shock. Doors rattled, hanging objects swung, his seat was shaken and he went out of doors. Walls of almost all the buildings were cracked more or less and a portion of the roof of the first floor of an old building collapsed. Fire and smoke issued from fresh fissures in the 'fire areas' of Jharia and Bagdigi.

S. Alexander.—Time 2·16 p.m. Duration 200 seconds. He felt three tremors of which the second was the strongest. Loose objects were thrown down and walls of buildings were cracked.

R. K. Bose, Inspector of Works, E. I. R.—One shock for 120 seconds. Several buildings were cracked.

Rev. J. Dohet, S.J.—He was driving his car between Asansol and Sitarampur and on a certain climb of the road, at about the time of the quake, he felt an unusual, sudden but momentary failure of power without knowing that it was due to the earthquake, of which he learnt on his arrival at Dhanbad.

Pradhankhanta.

P. W. Inspector, E. I. R.—One shock for 180 seconds accompanied by a rattling sound. Doors and windows rattled, hanging objects swung, the observer's seat moved and walls of some buildings were cracked.

Kashipur.

Abdul Majid, Sub-Inspector of Police.—Duration 160 seconds. Several shocks during which a rumbling noise as of an aeroplane was heard. The replies are in accord with isoseismal VI.

Jhalda.

H. N. Mukerji, Sub-Inspector of Police.—Duration 180 seconds. Three separate but continuous shocks during which a rumbling as of an aeroplane was heard. Most people felt the quake, loose objects were thrown down and walls of buildings were slightly cracked.

Purulia.

Rai Sahib P. N. Mukherji, Sadar S. D. O. in Charge, Manbhum.—Duration 190 seconds. He felt two shocks during which he heard at first a rumbling noise like that of a heavy lorry passing at a distance and later like the droning of an aeroplane flying overhead. The shocks were felt by persons at rest, doors and windows rattled and his clock swung out of line and stopped. A stationary motor car first swayed east-west and then north-south. Some buildings were slightly cracked.

Hura.

J. N. Mukerji, Sub-Inspector of Police.—Duration 210 seconds. One severe shock was felt during which a rumbling noise as of an aeroplane was heard. Doors,

windows, tiles, etc., rattled, and walls arches and compound of the police station were cracked. None could remain sitting. Plaster, photos, etc., fell. About 30 per cent. of the houses in the jurisdiction of the thana were cracked and one house collapsed. Water in wells and tanks was badly shaken.

Baghmundi.

Officer in Charge, Baghmundi Police Station.—One strong shock preceded by a rumbling noise as of a motor car.

Bandwan.

Officer in Charge, Bandwan Police Station.—Two shocks for 60 seconds. A rumbling noise was heard during the shock, which was felt by persons at rest. Doors and windows rattled, hanging objects swung, loose objects were thrown down and walls of buildings were cracked.

SANTAL PARGANAS.

Pakaur.

H. N. Jha, Kanungo.—Duration 120 seconds. One shock during which a rumbling noise was heard. Persons at rest felt the shock, doors and windows rattled, loose objects fell and the observer's seat moved. The S. D. O.'s Court building sustained slight damage and the sub-jail and half a dozen private houses were slightly cracked.

Mrs. S. G. Hughes.—Duration 300 seconds. One continuous shock, causing doors and windows to rattle and the observer's seat to shake. Hanging plants on the verandah swayed east-west and ceiling lights and fans swayed in a circular fashion. Several houses, the Court and the Raja's palace had cracks in the walls.

Jamtara.

Rai Sahib S. N. Sen, Subdivisional Officer, Jamtara.—Duration 240 seconds. A continuous series of shocks preceded by a rumbling noise coming from beneath the floor and resembling the approach of a motor car. Doors and windows rattled, *punkahs* swayed and clocks stopped. Plaster fell and almost all the public buildings were more or less cracked.

Karmatar.

P. W. Inspector, E. I. R.- One continuous shock for 180 seconds. It was accompanied by sounds like the rumbling of an approaching train which increased till they resembled the noise of heavy machinery set in motion. Buildings rocked north-south, the floor heaved upwards during the violent shock, followed by the ground rotating east to west for 60 seconds after which the shock gradually abated. Tiles from the roofs of huts were shaken off and walls of a number of buildings were cracked.

Bengal.

BIRBHUM DISTRICT.

Dubrajpur.

B. L. Sen, Circle Officer.—One continuous shock preceded by a rattling sound as of a railway train and which persisted during the shock. Doors rattled, hanging

objects swung north-south and the observer's seat was shaken. Walls of some buildings were cracked.

Bolpur.

C. P. Roy, Circle Officer.—A rumbling noise was heard before and during the shock. Walls of buildings were cracked to a small extent.

Suri.

P. P. Pal, Circle Officer, Sadar.—Two shocks, the second being more severe than the first. Minor cracks appeared in the walls.

BURDWAN DISTRICT.

Asansol.

D. M. S. Robertson, E. I. R.—Several shocks for 240 seconds during which a rumbling noise was heard. Slight shocks were felt two hours afterwards. Doors rattled, hanging objects swung, loose objects fell down and walls of some buildings were cracked. The parapet of the Loreto Convent collapsed towards the south-west.

N. Banerjee, E. I. R.—A slight movement followed by a heavy shock. Duration 180 seconds. During the earthquake a rumbling noise was heard. A few buildings in the railway colony were cracked.

G. B. Mukherjee, Chairman, Municipality.—Two shocks felt by all. Doors and windows rattled, hanging objects swung N. E.—S. W. and a few old buildings were cracked.

Pravakar Rajguru.—Four shocks were felt. The observer's seat moved and he thought that the movement was east-west. Walls of some buildings were cracked.

Chinchuria, Asansol P. O.

Mrs. W. Goodger.—Two separate shocks accompanied from start to finish by a dull booming sound like that of a heavy motor. A corner of a bungalow collapsed, a cement water tank cracked and some roofs were cracked. A number of birds resting on a tree flew away with nervous cries at the first shock and did not return until night.

Hirapur, Burnpur P. O.

F. Small, Bungalow A4.—His office clock stopped at 14·17 hours. Doors rattled for 30 seconds as if caused by a gust of wind. Electric ceiling fan first swung north-south and then in a circular motion, the diameter of the circle being 18 inches approximately. Out of doors the ground shook, the duration of the shock being 120 seconds. Water in waterworks reservoir tilted more than 12 inches. Slight cracks appeared in walls over arches built north-south, none over east-west arches.

Raniganj.

A. G. Guha Roy, Chairman, Municipality.—One continuous shock alternately increasing and decreasing in intensity. A rumbling noise was heard just a second before the final heavy stage of the shock. Doors and windows rattled, hanging objects swung north-south and loose objects fell. Several cracks appeared from top to bottom of the old buildings. Portion of a parapet of a two-storey building and a small room on the terrace of a double-storey building collapsed.

Katwa.

Sanitary Inspector.—Three shocks preceded by a rumbling noise as of an approaching storm. Doors and windows rattled, hanging objects swung, loose objects fell and walls of buildings were cracked. One old two-storey building collapsed.

Burdwan.

Vice Chairman, District Board.—One continuous shock felt by all. Doors and windows rattled, hanging objects swung north-south and loose objects fell both north and south. Walls of some buildings were cracked.

Municipal Engineer.—Three shocks causing hanging objects to swing north-south. The observer's seat moved and a few buildings were slightly cracked.

Chakdighi.

Raja M. L. Singh Roy, C.I.E.—Duration eight minutes. Three shocks of which the first two were east-west and the last clock-wise. Doors and windows rattled and the observer's seat moved. Walls of several buildings were cracked.

Kalna.

Subdivisional Officer.—First shock was followed by a second and severer shock. Birds perching on trees flew. Doors and windows rattled, hanging objects swung and the observer's seat moved. Some fifty buildings were slightly cracked.

Kalipada Chatterjee.—Three separate shocks were felt. Hanging objects swung north-south and the observer's seat moved in the same direction. Walls and floors of buildings were slightly cracked.

BANKURA DISTRICT.

Bankura.

P. N. Chatterjee, Chairman, Municipality.—Two shocks during which some unusual sounds were heard. Doors and windows rattled, hanging objects swung north-south and the observer's seat moved. Slight cracks appeared in the walls of old buildings.

Bishnupur.

Subdivisional Officer.—A sound like that of a motor engine was heard before and during the shock, which most people felt. Doors and windows rattled and hanging objects swung north-south.

T. Gupta, Sanitary Inspector.—One shock felt by many persons. It was preceded by a rumbling noise like that of a motor car which ended with the shock. Hanging objects swung north-south, the observer's seat moved and loose objects fell. Walls of some buildings were cracked and one mud wall collapsed.

Raipur.

Circle Officer, Raipur.—Two shocks felt by everybody. Doors and windows rattled, hanging objects swung and the observer's seat moved. Old buildings were cracked.

MIDNAPORE DISTRICT.

Ghatal.

R. Dutta, Subdivisional Officer.—He felt three shocks. Doors and windows rattled, hanging objects swung and the observer's seat was shaken. A window of the S. D. O.'s house was disjointed.

HOOGHLY DISTRICT.

Arambagh.

A. N. Sahana, Vice Chairman, Municipality.—Several shocks preceded by a sound like that of an aeroplane at a distance. The sound lasted throughout the quake. The observer's seat moved, loose objects fell and some buildings were slightly cracked.

Tarakeswar.

Sub-Inspector of Police.—One shock with an east-west movement.

Rishra-Konnagar.

N. N. Banerjee.—Three major shocks and several tremors which were preceded by a sort of rumbling noise. Doors and windows rattled, hanging objects swung, the observer's seat moved and loose objects were thrown down. The movement was felt to be north south but the middle shock was east-west.

Magra.

K. B. Chatterjee, Sub-Inspector of Police.—Three shocks of which the middle one was the strongest. Movement was east-west. Walls of some buildings were cracked.

Hooghly.

S. Huq, Sub-Inspector of Police.—Just before and during the earthquake a sound like that of an aeroplane was heard. Hanging objects swung east-west and the observer's seat moved in the same direction.

Chinsurah.

M. C. Ghosh, Subdivisional Officer.—Several shocks shook his seat on the dais of the court room. Some buildings were slightly cracked.

Chairman, Hooghly-Chinsurah Municipality.—Two shocks felt by most people, doors rattled, hanging objects swung north-south and the observer's seat moved. Loose objects were thrown in a north-south direction and some buildings of the town were cracked.

A. C. Kar, Sub-Inspector of Police.—Two shocks of which the first was east-west changing later to north-south.

Bansberia.

W. Robertson, Manager, Bansberia Jute Mills.—Several shocks felt by most people. Lamps swayed east-west and some walls were cracked.

Bhadreswar.

Vice-Chairman, Municipality.—Two shocks, N. E.—S. W. and east-west. Walls and roofs of some buildings were slightly cracked.

Champdani.

B. B. Chatterjee.—Two shocks. Hanging objects first swung east-west and then north-south. Walls of some buildings were cracked.

Serampore.

L. A. Chapman, Subdivisional Officer.—Two shocks for 240 seconds, doors and windows rattled, hanging objects swung and the observer's seat moved. The first movement was north-south and then east-west. One slight crack appeared in the wall of the court building, which is old.

A. Mukherjee, Overseer.—Four shocks. Doors and windows rattled, hanging objects swung east-west and a few old buildings were slightly cracked.

Uttarpara.

Chairman, Municipality.—The pendulum clocks on east and west walls stopped at 14·15 hours, those on north and south walls generally did not stop. The first shocks were of mild intensity and were followed by severer ones. Doors and windows rattled, trees swayed and rustled. The first movements were west-east and later they were N. E.—S. W. Water of a tank rolled east-west and then S. E.—N. W. Slight cracks appeared over the arches of old buildings.

HOWRAH DISTRICT.

Amta.

H. S. Mukherjee, Circle Officer.—The earthquake was felt universally and caused doors and windows to rattle. Hanging objects swung and the observer's seat moved.

Howrah.

U. N. Das Gupta, Circle Officer, Sadar.—Two severe and a few mild shocks. Hanging electric lamps swung north-south. A few houses were slightly damaged.

Uluberia.

N. C. Sen, Subdivisional Officer.—He felt one continuous shock causing doors and windows to rattle. Hanging objects swung east-west. Some buildings were cracked.

Calcutta.

Dr. A. N. Coulson's note, written a few minutes after the earthquake, has been already reproduced on page 24.

J. Chaudhuri, Bar-at-Law, Editor, Calcutta Weekly Notes, 34, Ballygunge Road.—Doors on the east and west side of the house rattled. Water in a tank moved up the steps in a mass the clear surface of the water remaining calm in the middle. Floating weeds moved from east to west. The clock on the north-south wall stopped, that on the east-west wall did not. A corner of the southern verandah of the second floor of 3, Hastings Street, a very old building, came down.

S. C. Ghosh, 1-1C, Uriyapara Lane, Entally.—A slight shock followed by a stronger one and then diminishing in intensity. Electric lights swung east-west. An east-west wall on the southern side of the house was slightly cracked.

Satis Chandra Basu, 54, Hari Ghosh's Street.—An up and down movement followed by the following movements :—spiral N. E. to S. E., oscillatory N. E.—S. W., circular upheaval rising towards south-west, oscillatory sinking towards north-east. A rumbling noise was heard at the beginning which was drowned later by the rattling of furniture, doors and windows. Ceiling fans swung N. E.—S. W. Hanging electric lamps drew elliptical curves in the air, the major axis of the

ellipse being N. E.—S. W. A tremendous spiral rising movement from N. E. to S. E. was observed, the vertical impact was far greater than the slight oscillation which accompanied it, the action increasing and decreasing gradually except for a single jerk in the middle of the shock.

24-PARGANAS DISTRICT.

Dum Dum.

Officer in Charge, Police Station.—One shock causing hanging objects to swing north-south. Most people felt the shock.

Titagar.

Officer in Charge, Police Station.—Two shocks felt by most persons. Doors and windows rattled, hanging objects swung east-west. Small cracks appeared in some buildings.

Barrackpore.

Officer in Charge, Police Station.—Two shocks felt by most people. Doors and windows rattled, hanging objects swung and some cracks appeared in walls over the arches.

Naihati.

Officer in Charge, Police Station.—Two shocks felt by everybody. Doors rattled, hanging objects swung east-west, the observer's seat moved and loose objects fell down both east and west. Walls of some buildings were cracked.

Barasat.

K. K. Hazra, Subdivisional Officer.—Two distinct shocks were felt at first after which the shock was continuous. The shock was fairly strong and it was difficult to stand or walk steadily. Walls of buildings were cracked.

NADIA DISTRICT.

Krishnagar.

Subdivisional Officer.—Three shocks. Loose objects rattled, hanging objects swung east-west, and some objects fell in the same direction. Walls of a few buildings were cracked and an old wall fell down.

R. N. Sen, Principal, Krishnagar College.—Two shocks. The replies to the questions are in accord with isoseismal VI.

Chuadanga.

Sub-Deputy Magistrate.—One continuous shock felt by many people. Doors and windows rattled, the observer's seat moved and hanging objects swung east-west.

Meherpur.

S. Sarker, Subdivisional Officer.—One continuous shock felt by all. Doors rattled, hanging objects swung east-west, the observer's seat moved and slight plaster cracks appeared in a few buildings.

Murshidabad district.

Jangipur.

S. C. Das Gupta, Circle Officer.—Very narrow fissures, about an inch wide, aligned north-south on the *chars* (shoal) close to the water level, on both the banks of the Bhagirathi river. Some cracks appeared in *pucca, semi-pucca* brick buildings and mud huts.

Murshidabad.

Subdivisional Officer, Murshidabad.—Two shocks with an imperceptible break. A deep roaring was heard. Doors and windows rattled, branches of trees swayed as in a storm. Hanging objects swung north-south and loose objects fell north. Walls of buildings were cracked and portions of old walls and buildings collapsed.

Lalbagh.

Subdivisional Officer, Lalbagh.—The shock was accompanied by a rumbling noise and was felt by most people. Doors rattled, hanging objects swung N. E.—S. W., and loose objects were thrown in the same directions. Walls of buildings were cracked and many old buildings in the town partially collapsed.

Berhampur.

S. N. Roy, Medical Officer.—One shock gradually increasing in intensity and then dying out. A rumbling sound was heard during the shock, which was felt by most people. Hanging objects swung, loose objects were thrown down and walls of buildings were cracked. Some walls and portions of old buildings collapsed.

Jessore district.

Bangaon.

Subdivisional Officer, Bangaon.—He felt about half a dozen shocks. Doors and windows rattled, hanging objects swung east-west, his seat was shaken and walls of some old buildings were cracked.

Jessore.

Sudhir K. Basu.—One uniform shock which was felt by many people. Branches and leaves swung north-south. No sound was heard at Jessore.

Jhenida.

Dhirendra N. Roy.—One shock for 300 seconds. Some people were unable to stand and some felt giddy. A mango tree was vigorously shaken. A north-south movement was felt and a number of buildings were cracked.

Magura.

Subdivisional Officer, Magura.—One shock felt by many persons. Doors and windows rattled, hanging objects swung north-south and his seat moved.

Faridpur district.

Faridpur.

B. M. Chatterjee, Meteorological Observer.—Four shocks for 180 seconds. People at rest felt the shocks, hanging objects swung and loose objects fell. Walls of some buildings were cracked.

Dacca district.

Dacca.

B. C. Prance, Collector.—Five or six shocks which were felt by persons at rest. Doors and windows rattled, fans, etc., swung north-south and his seat moved. A few buildings were cracked.

Mymensingh district.

Tangail.

M. J. Carritt, S. D. O.—One continuous shock with a slight rumbling as of heavy traffic at a distance. It was felt by most people, doors and windows rattled, and loose objects fell. Several buildings were cracked.

Mymensingh.

J. K. Sen, Inspector of Police.—A mild shock was followed by a second one of great intensity, and was preceded by a rumbling noise. Trees shook violently and water in a tank rose to a height of about 30 inches. The observer's seat was shaken, loose objects fell and some buildings were cracked. The direction of movement was north-south.

A. Ghazi.—One continuous shock for 180 seconds. The replies are in accord with isoseismal VI.

Netrakona.

B. N. Chakravarty, S. D. O.—One severe shock causing doors and windows to rattle. Hanging objects swung east-west. The Dispensary, Jail and some private buildings were cracked.

Pabna district.

Pabna.

K. Bagchi, Deputy Magistrate.—Several shocks in quick succession at an interval of 40-60 seconds. The shocks were preceded by a rumbling noise as of a train at distance or the approach of a rain storm. All clocks placed at a height of 12 feet or more from the ground stopped, those below this height did not all stop. The first movements were definitely east-west but changed to north-south. A boy riding on a bicycle in a north-south direction was thrown down. Western and eastern walls in some buildings had small plaster cracks.

S. C. Dutt, Assistant Engineer.—Three shocks travelling in a N. W.—S. E. direction. A rumbling sound was heard at the commencement of the shocks. Trees shook slightly and some east-west walls were slightly cracked.

Rajshahi district.

Rajshahi.

A. S. Larkin, District Magistrate, Rajshahi Dist.—Three shocks preceded by a rumbling noise like that of an omnibus at a distance. Doors and windows rattled, hanging objects swung east-west, loose objects were thrown down in the same direction, the observer's seat moved and walls of some buildings were cracked.

Nator.

J. N. Sanyal, Medical Officer.—Several continuous shocks felt by persons at rest. Doors rattled, hanging objects swung and his seat moved.

A. K. Chakraburty, Headmaster, High School.—One continuous shock in a N. W.—S. E. direction.

B. N. Banerjee, Stationmaster, E. B. R.—Three shocks. Some walls of the station buildings were cracked.

Dighapatia.

D. N. Chakraburty, Headmaster, High School.—A rumbling noise was heard during the shock, which had a to and fro motion. Doors and windows rattled and loose iron posts swayed east-west.

Naogaon.

P. M. Dutt.—A continuous oscillating movement in a N. W.—S. E. direction was felt. A sound like that of a motor car was heard before the shock. Walls of some buildings were cracked.

MALDA DISTRICT.

Nawabganj.

Circle Officer.—Two shocks. During and after the shocks a sound resembling the passing of a car at a distance was heard. Doors and windows rattled, hanging objects swung east-west and the observer's seat moved. Some of the walls of old buildings were cracked over door and window openings.

Malda.

S. Rahman, S. D. O., P. W. D.—One continuous shock, making standing difficult. Hanging objects swung north-south.

R. Das, Meteorological Observer.—Two shocks preceded by a rumbling noise like that of a motor car. The sound continued during the shocks. Doors and windows rattled, hanging objects swung north-south, the observer's seat moved and *pucca* and *semi-pucca* buildings were cracked. One or two verandahs collapsed.

Sibganj.

A. T. Mandal, Headmaster, M. E. School.—One shock preceded by a rumbling noise. Doors and windows rattled, hanging objects swung north-south and the observer's seat moved.

Chandpur, Chowdala P. O.

Muhammad L. Rahman, Headmaster, M. E. School.—Two shocks accompanied by a rumbling noise as of an aeroplane. Hanging objects swung east-west; east-west walls of some *pucca* buildings were cracked.

BOGRA DISTRICT.

General (Bogra dist.).—A large number of reports from various parts of Bogra district show that a rumbling noise was heard before and during the shocks, several in number according to some and one continuous shock according to others. The majority of reports are in favour of an east-west movement, but others are equally divided between N. W.—S. E. and N. E.—S. W., and some observed a north-south movement. Doors and windows rattled, and the shaking of the observer's seat was a common feature. Loose objects were thrown down and walls of buildings were slightly cracked in some places.

Bogra.

B. B. Mukherjee, S. D. O., P. W. D.—A series of tremulous vibrations for 150 seconds. The apparent direction of the shock was north-south; the pendulum of the office clock, fixed on the east wall, stopped after the quake was over. A sound, like that of a lorry, was heard travelling east-west and it lasted about 30 seconds. Some east-west walls were slightly cracked.

H. P. Roy, Superintendent, Edward Industrial School.—One shock preceded by a sound like that of a motor bus in motion. Doors rattled, hanging objects swung north-south, the observer's seat moved and small cracks appeared here and there on the walls.

District Sub-Registrar.—Three shocks preceded by a faint noise as of a motor car at distance. Hanging objects swung north-south. Doors and windows rattled, and some people felt a N. W.—S. E. movement.

Hili.

S. N. Gupta, Headmaster, Rama Nath H. E. School.—One continuous shock lasting 240 seconds. It was preceded by a rumbling noise which continued till the end. Persons at rest felt the shock, doors and windows rattled, hanging objects swung and the observer's seat moved.

DINAJPUR DISTRICT.

Balurghat.

P. C. Sen, Subdivisional Officer, Balurghat.—One vibration was followed by a pulsating upward movement and finally by another vibrating movement. A noise like that of a motor car was heard. Doors rattled and some buildings were cracked.

Dinajpur.

B. C. Sen, Subdivisional Officer, Dinajpur.—One continuous shock with a rumbling sound. Doors rattled, hanging objects swung, the observer's seat moved and loose objects fell. Walls of some buildings were cracked and plaster fell from some of the ceilings.

RANGPUR DISTRICT.

Gaibandha.

S. C. Bagchi, Subdivisional Officer, Gaibandha.—One shock varying in intensity and accompanied by a rumbling noise. Movement appeared N. W.—S. E. Doors and windows rattled, hanging objects swung and the observer's seat moved. Minor cracks appeared over arches.

Rangpur.

M. Das Gupta, Subdivisional Officer, Sadar.—One shock for 80 seconds. Hanging objects swung east-west, the observer's seat moved and some buildings were cracked.

Kurigram.

Subdivisional Officer, Kurigram.—Three shocks, of which the first was the strongest. The replies are in conformity with isoseismal VI.

Lalmanirhat.

T. S. S. Ayre.—Felt a side to side and a circular (rotatory) movement which lasted about 300 seconds. Trees in the compound swayed in all directions and a rumbling noise was heard.

Nilphamari.

K. Mitra, Subdivisional Officer, Nilphamari.—A series of intense shocks, during which a rumbling sound like the booming of cannon at a distance was heard. Doors rattled, hanging objects swung, loose objects fell and some of the arches of *pucca* buildings were cracked.

JALPAIGURI DISTRICT.

Goyerkata (Western Duars).

Subdivisional Officer, P. W. D.—Two shocks preceded by a booming sound. Doors and windows rattled, the observer's seat was shaken and a few walls had slight surface cracks.

Dhupguri.

S. C. Dutt, Dhupguri Police Station.—Two shocks felt by many persons. The replies are in accord with isoseismal VI.

Alipur Duar.

R. N. McWilliams, S. D. O.—One shock felt by persons at rest. Doors and windows rattled, hanging objects swung, loose objects fell down and his seat moved. Some cracks appeared in plaster.

Subdivisional Officer, P. W. D., Eastern Duars Subdivision.—A sound like that of a rushing storm was heard during the shock. Punkah poles, 16 feet long, swung up to five feet. Water from bath tubs all full, up to 16 inches, splashed out leaving about one-third. Arches of *pucca* buildings were slightly cracked and the floors and stairs of a wooden frame building were partially dislocated. A dry shoal, one foot high, in the bed of the Kaljani river was flooded over.

COOCH BEHAR STATE.

Dinhata.

N. N. Roy.—More than three shocks, which were felt by many persons. Doors rattled, hanging objects swung and trees swayed east-west. His own seat was shaken.

Matabhanga.

M. M. Ganguly, Inspector of Police.—One shock consisting of a series of pulsations. A sound like the distant rumbling of thunder was heard from the north-west. Doors and windows rattled and the observer's seat moved. Loose objects fell either north-west or south-east. Very slight cracks appeared in some buildings.

Cooch Behar.

S. C. Bhattacharjee, Subdivisional Officer, Cooch Behar.—A low rumbling sound was heard during the one continuous shock. Trees and houses shook violently, doors and windows rattled. Electric fans swayed north-south. Seats moved vehemently, loose objects fell northwards. Walls of many buildings were cracked.

U. N. Dutt, Fouzdari Ahilkar.—Two shocks, preceded by rumbling noise as of a motor car at a distance. Doors and windows rattled, hanging objects swung N. W.—S. E. Walls of buildings were slightly cracked.

Principal, Victoria College.—Several shocks of varying intensity. Walls of some buildings were cracked.

M. N. Roy, Headmaster, Jenkins School.—Three shocks. Hanging objects swung east-west, a few walls had very small cracks. The tiled roof of a small verandah on the western side of the main *pucca* school building was detached from the wall and sank about two inches.

B. Bose.—One very strong shock during which a humming noise was heard. Trees and houses were shaken and many people felt it difficult to remain standing. Loose objects were thrown down, floors and walls of many buildings were cracked and a few buildings were badly damaged.

Tufanganj.

Subdivisional Officer, Tufanganj.—One continuous shock preceded by a rumbling noise as of a motor car. Doors and windows rattled, hanging objects swung and the observer's seat moved. Walls of buildings were slightly cracked.

Assam.

Goalpara district.

General.—Reports from several villages along a narrow strip of the country, on both sides of the Brahmaputra between Dhubri and Goalpara, show that the shock felt there was stronger than that in the rest of Goalpara district. A number of buildings were slightly cracked and a rumbling noise was heard simultaneously with the shock in some cases.

Dhubri.

D. N. Dey, Meteorological Observer.—He felt six continuous shocks lasting about 175 seconds. The earthquake was felt by persons at rest and was strong enough to make doors, windows, etc., rattle, to make hanging objects swing and to throw down loose objects. Walls of some buildings were cracked.

M. A. Choudhury, Police Station.—He felt one shock for 90 seconds.

Goalpara.

M. H. Hussain, Subdivisional Officer, Goalpara.—He felt one shock for 100 seconds which was strong enough to throw down loose objects and to crack the walls of buildings. Hanging objects swung.

Gauripur.

D. C. Chuckerburty, Dewan, Gauripur Raj Estate.—One shock for 180 seconds, causing doors and windows to rattle. Some plaster fell. Old cracks in some houses enlarged slightly and bricks fell from an already damaged house.

ISOSEISMAL ?VI.

A small area in the extreme south of the Gangetic delta in Bengal experienced an intensity which can be expressed partly by isoseismal VI and partly by V. The area has been separated from either and included in a separate isoseismal marked ?VI.

Bengal.

24-PARGANAS.

Basirhat.

Circle Officer.—Three shocks felt by persons at rest. Doors and windows rattled and hanging objects swung east-west.

Sub-Registrar.—Two or three shocks. Movement east-west.

Hasanabad.

Sub-Registrar.—A preliminary shock followed by three shocks of greater intensity. A few seconds before the first shock a rumbling noise as of an aeroplane at a great distance was heard, the sound continuing during the shock. Doors and windows rattled and hanging objects swung east-west.

KHULNA DISTRICT.

Mollahat.

M. Ali Mollah, Overseer, Irrigation.—One strong shock for 300 seconds. Doors rattled, hanging objects swung north-south and the observer's seat moved.

Khulna.

A. R. Bose, Subdivisional Officer, Khulna.—One continuous shock felt by persons at rest. Doors and windows rattled, hanging objects swung east-west. Some buildings were slightly cracked.

L. B. Sen Gupta, Meteorological Observer.—Hanging objects swung north-south and loose objects fell to the south.

S. Ghosh, Sectional Officer.—Three shocks felt by persons at rest. Hanging objects swung N. N. E.—S. S. W.

Surkhali.

T. Chakraburty, Sub-Overseer.—One mild shock felt by some persons. Hanging objects swung east-west. Doors and windows slightly rattled.

Satkhira.

Subdivisional Officer, Satkhira.—One shock for 150 seconds. It was felt by persons at rest, hanging objects swung east-west and the observer's seat moved.

Bagerhat.

A. N. Roy, Sub-Inspector of Police.—Two shocks for 120 seconds. Hanging objects swung north-south and the observer's seat moved.

Morrelganj.

N. Ahmad, Sub-Inspector of Police.—One shock for 150 seconds felt by persons at rest. Hanging objects swung north-south and the observer's seat moved.

BAKARGANJ DISTRICT.

Pirojpur.

J. N. Sarkar, Head Clerk, S. D. O.'s Court.—Three shocks felt by many persons. Doors and windows rattled, hanging objects swung N. W.—S. E., the observer's seat was shaken and loose objects fell towards the south-east. Walls of some buildings were cracked.

Barisal.

Executive Engineer.—Three shocks felt by most persons. Doors rattled, hanging objects swung and the observer's seat moved. Water in a borrow-pit on the river bank oscillated east-west. North and south walls of tall buildings were cracked and the Collectorate building was rather badly damaged. Another report from Barisal says that two strong shocks in quick succession were felt. Hanging objects swung N. W.—S. E.

Lieut. K. A. Majumdar, S. D. O., Sadar Subdivision (North), North Barisal.—Six shocks felt by persons at rest, doors and windows rattled, hanging objects swung east-west and the observer's seat moved.

Sherpur.

N. Sarkar, Sub-Registrar.—One shock for 210 seconds. A rumbling noise, as of a motor car, was heard before the shock, which was felt by all persons. Hanging objects and trees swayed N. W.—S. E. and the observer's seat was shaken.

Dhunat.

R. Idris, Sub-Registrar, Dhunat.—Five shocks for 180 seconds. Before and during the shocks a sound like that of a motor bus was heard. Doors and windows rattled, hanging objects swayed N. W.—S. E., the observer's seat moved and walls of some buildings were cracked.

JESSORE DISTRICT.

Narail.

Subdivisional Officer, Narail.—One continuous shock for 300 seconds, which was felt by all. Doors and windows rattled and hanging objects swung north-south.

MYMENSINGH DISTRICT.

Kishorganj.

R. K. Bhattacharjee, S. D. O., Kishorganj.—One continuous gentle shock. Hanging objects slightly swung north-south. Some buildings were slightly cracked.

CHAPTER XXVI.

ISOSEISMAL V+.

A small portion of the delta of the Mahanadi in eastern Orissa has been included in isoseismal V+. Here the intensity of the shock was slightly greater than in the rest of Orissa, which falls within isoseismals V and IV.

Eastern States.

TIGIRIA STATE.

Tigiria.

Sub-Inspector of Police, Tigiria Police Station.—One shock for 180 seconds. It was preceded by a rumbling noise as of a passing motor car. Doors and windows rattled, hanging objects swung north-south, and his chair rocked a little. Some walls were cracked.

ATHGARH STATE.

Athgarh.

Deonarayan Prasad.—One continuous shock for 90 seconds. It was felt by persons at rest, hanging objects swung east-west, and the table on which he was writing moved. Walls of some buildings were cracked.

DHENKANAL STATE.

Dhenkanal.

Subdivisional Officer, Sadar.—One shock lasting about 180 seconds. A rumbling noise was heard during the shock, which was felt by persons at rest. Doors, windows and loose objects rattled and hanging objects swung north-south. Slight cracks in walls.

Orissa.

CUTTACK DISTRICT.

Cuttack.

S. Dilwar Ali, Cuttack.—One moderately severe shock for 336 seconds, felt by many people. Chairs and tables moved backwards and forwards. The electric wire post on the top of the *ijlas* swayed north-south. The observer's seat moved and walls of some buildings were cracked.

Mrs. C. A. Marchant, Winifred House, Ranihat, Cuttack.—One jolt followed by severe movements making her feel sick. Duration 300 seconds. Water in a tub splashed two and a half inches, at first it moved N. E.—S. W. and then in a circular fashion. The shock woke up a sleeping person. Doors and windows rattled, hanging lamps swung and her bed was shaken.

Jajpur.

Subdivisional Officer, Jajpur.—He was sitting in court trying a case when, at 14·15 hours, his seat trembled and he felt a shock which lasted about 240 seconds and was heralded by a rumbling noise like that of an aeroplane flying overhead. Doors, windows, chairs, tables, etc., rattled and many people felt giddy. The branches of a *peepul* tree swayed N. W.—S. E.

B. B. Babu.—He felt one shock lasting 180 seconds. Just previously there was a rattling sound, which resembled that of the tail end of distant thunder. Doors and windows rattled, hanging objects swung north-south, and the observer's seat moved. The floor and walls of the local Post Office and those of the Sub-Registrar's Office were slightly cracked.

ISOSEISMAL V.

Punjab.

KARNAL DISTRICT.

Panipat.

Khan Sahib Khan Ahmad Haran Khan, Deputy Commissioner.—Half a dozen mild shocks for 60 seconds, which were felt by many persons. Doors and windows rattled and hanging objects swung north-south.

ROHTAK DISTRICT.

Rohtak.

H. Lincoln, Deputy Commissioner.—One long tremor for 120 seconds. Doors and windows rattled, hanging objects swung north-south. The Treasury office, an old building, had a crack or two in the east-west wall from top to bottom.

GURGAON DISTRICT.

Gurgaon.

A. Hussain, Deputy Commissioner.—Three shocks for 90 seconds in quick succession, the middle one being quite severe. Doors and windows rattled, hanging objects swung and the observer's seat moved. A few buildings were slightly cracked. An increase in the water and temperature of the hot sulphur springs of Sohna was reported when the shock was fairly strong.

LOHARU STATE.

Loharu.

S. M. Tahir, Secretary, Loharu State.—One shock lasting about 60 seconds. A sound as of a railway train in motion was heard. Small loose objects rattled slightly and hanging objects swung. The observer's seat moved and walls of some buildings were cracked.

United Provinces.

Dehra Dun district.

Chakrata.

Assistant Superintendent.—Two strong shocks for 60 seconds which vigorously shook his seat and writing table.

Bhatta, Mussoorie.

Janki Nath.—Two shocks felt by persons at rest. Doors and windows rattled hanging objects swung N. W.—S. E. and the observer's seat moved.

Dehra Dun.

Haig Observatory, Survey of India.—One shock recorded by seismograph at 14h. 15m. 14s. (I. S. T.). The duration of the shock as recorded by the seismograph needle was 3h. 50m. 00s. The shock was felt by persons at rest and caused hanging objects to swing.

G. Acton, District Magistrate.—One continuous oscillation for five seconds. There was a rapid movement of the ground in a N. E.—S. W. direction. Electric lamps swung slowly north-south about six inches each way. The Forest Research Institute was very slightly cracked.

H. E. Rodrigries, P. W. Inspector, E. I. R.—One shock. Wall clocks stopped, hanging objects swung and his seat rocked.

Raiwala.

M. Ganapati.—The observer was in a railway carriage which was standing at Raiwala station. He felt three shocks which slightly shook his seat.

Garhwal district.

Pauri.

R. P. Khanduri, Kanungo.—Two shocks during and after which a faint sound as that of distant thunder was heard. Doors, windows and loose objects rattled a little.

Chamoli.

S. Singh, Naib Tahsildar.—Two shocks which travelled from the south-east. Doors and windows rattled, hanging objects swung and his seat moved. Walls of some buildings were slightly cracked.

Jamnagar.

P. Robertson, Deputy Conservator of Forests.—A continuous tremor with three or four more violent phases lasting 130 seconds. Shaking of floor made standing uneasy. The table lamp rocked east-west and some plaster fell from the roof of the rest house. Boulders (Siwalik conglomerate) were dislodged from cliffs and leaves of trees quivered.

Saharanpur district.

Saharanpur.

Civil Surgeon.—One shock causing doors and windows to rattle. Electric lights swung east-west and pictures moved in the same direction.

Roorkee.

B. J. Puri, Meteorological Observer.—One shock lasting 60 seconds. The shock was felt by persons at rest and caused doors to rattle. Hanging objects swung and his seat moved.

Laksar.

Ram Prasad.—Two or three shocks which were felt by persons at rest. Doors and loose objects rattled, hanging objects swung, his seat moved and some loose objects were thrown.

MUZAFFARNAGAR DISTRICT.

Muzaffarnagar.

The Collector.—He felt three shocks of which the last was the strongest. Duration 80 seconds. Hanging objects swung east-west.

BIJNOR DISTRICT.

Najibabad.

A. N. Kapoor, Inspector of Works, E. I. R.—Two continuous shocks of which the second was the more severe. Doors and windows rattled, hanging objects swung, and his seat moved.

Bijnor.

Naib Tahsildar.—Three shocks. Loose objects rattled and hanging objects swung east-west.

MEERUT DISTRICT.

Hapur.

Amar Singh, Inspector of Works, E. I. R.—One continuous shock accompanied by unusual ringing and creaking sound due to doors and windows. His chair shook. The shock did not awaken sleeping people.

BULANDSHAHR DISTRICT.

Bulandshahr.

R. Johnston, Collector.—One strong initial shock followed by minor tremors. Water in a pot was agitated for 120-180 seconds. The direction of the shock appeared to be east-west.

S. S. Pathak.—Two shocks felt by persons at rest. Doors and windows rattled and hanging objects swung. Some walls were cracked.

MORADABAD DISTRICT.

Moradabad.

A. O. Evans.—Two shocks. The lawn moved in waves after the manner of a corrugated iron sheet.

M. S. Ahmad, A. S. W., E. I. R.—Two shocks. Doors and windows rattled and hanging objects swung. Some of the bungalows were slightly cracked.

Choudhri Ram Bahadur, Tahsildar.—One continuous movement with two shocks. Hanging objects swung north-south.

BUDAUN DISTRICT.

Gunnaur.

Pandit Chandar Hans, Naib Tahsildar.—Duration 60 seconds. Those sleeping or walking did not feel the shock much. One shock causing doors, etc. to rattle was felt by persons indoors as their seats were slightly moved.

Bisauli.

Hari Sankar, Tahsildar.—One shock for 120 seconds. Doors and windows rattled, hanging objects swung and water in a bucket quivered. Persons resting felt the shock.

Sahaswan.

Ram Nath, Kanungo.—Three shocks lasting 240 seconds. A faint sound as of working motor machinery was heard. Persons at rest felt the shock, doors, and windows rattled and hanging objects swung north-south. His seat was shaken.

Budaun.

Pandit Sri Ram.—Two or three slight shocks for 90 seconds. Doors and windows rattled, hanging objects swung north-south and some loose objects were thrown either west or east. His seat was shaken north-south.

Dataganj.

Naib Tahsildar.—Two shocks in succession for 128 seconds. The shocks were felt by persons at rest, doors and windows rattled, hanging objects swung east-west and some loose objects were thrown westwards. Walls and arches of Dataganj Bench building were cracked.

ALMORA DISTRICT.

Bageswar.

F. N. Crofts, Assistant Commissioner.—He felt one shock which was accompanied by a slight rumbling noise as of distant thunder. Doors and windows rattled, hanging objects swung and his seat was shaken.

Almora.

B. B. Lal.—One continuous shock. Doors and windows rattled, and his bed rocked south-north.

NAINI TAL DISTRICT.

Mukteswar.

K. N. Tewari, Meteorological Observer.—A strong shock for 50 seconds was followed by a mild one for ten seconds. A rumbling noise was heard during the first shock. Doors and windows rattled, hanging objects swung and some loose objects were thrown down.

Ramnagar.

B. Abraham, Naib Tahsildar.—One moderate shock for 90 seconds. Doors and windows rattled and hanging objects swung.

Kashipur.

H. D. Paul, Chairman, Municipal Board.—Three shocks for 90 seconds. A 'hissing' sound as of an aeroplane in the distance was heard. Persons at rest

felt the shock, doors and windows rattled, hanging objects swung and the observer's seat moved. Walls of two buildings had a few cracks.

Baxpur.

J. Singh, Naib Tahsildar.—One continuous but slight shock for 120 seconds which was felt by persons at rest.

Haldwani.

H. B. Bhandari.—One slight shock for 180 seconds. Persons at rest felt the shock and doors and windows rattled.

PILIBHIT DISTRICT.

Pilibhit.

Moshin Ali.—Felt three strong shocks. The movements were east-west. Four or five walls were slightly cracked.

Headmaster, Drummond Government High School.—One continuous shock which caused hanging objects to swing east-west.

Rajputana.

AJMERE-MERWARA DISTRICT.

Ajmere.

Meteorological Observatory, Ajmere.—One continuous shock for 54 seconds at 14·15 hours. Persons at rest felt the shock, doors and windows rattled, hanging objects swung and some loose objects were thrown down. Walls of the Government High School building were cracked.

ALWAR STATE.

Nimrana.

Raj Bahadur, Diwan.—One strong shock for 180 seconds at 14·15 hours. He felt the shock whilst sitting on the second storey of his house; it caused doors and windows to rattle and loose objects to move. Hanging objects swung north-south and some loose objects fell either north or south.

JAIPUR STATE.

Jaipur.

Head Observer, Meteorological Observatory.—Several continuous shocks were felt travelling W. S. W.—E. N. E. Duration 300 seconds. Doors, windows, chairs, loose objects and the observer's table rattled. The observatory "chapper" (shed) showered dust and a portion of the *pucca* wall had a superficial crack.

Education Member, Council of State, Jaipur.—Two deserted buildings in a dilapidated condition in the Chaksu town collapsed.

JODHPUR STATE.

Sambhar.

The Hakim of Sambhar, Marwar.—About a dozen shocks for 90 seconds. Persons at rest felt the shock, which caused doors and windows to rattle and hanging objects to swing north-south. Walls of buildings had a few minor cracks.

KISHANGARH STATE.

Kishangarh.

K. Singh.—Generally there was one shock but in some places two shocks were felt. Total duration was three seconds. A sound like that of a motor lorry was heard. Doors and windows rattled, hanging objects swung N. E.—S. W., and his seat moved in the same direction.

LAWA STATE.

Lawa.

N. S. Narain, Kamdar, Lawa Chiefship.—Two shocks for 60 seconds. Most people felt the shocks. Doors, windows and loose objects rattled and hanging objects swung north-south. Some walls were cracked.

TONK STATE.

Tonk.

Member, State Council.—A slight earthquake shock sufficient to be felt by persons at rest and to make hanging objects swing.

Gwalior State.

UJJAIN DISTRICT.

Ujjain.

G. S. Apte, Superintendent, Shree Jiwaji Observatory.—One mild shock for 45 seconds. Roofs of corrugated galvanised sheet iron made a rattling noise. The shock was felt by persons on the upper storeys of houses, persons on the ground floor did not feel it. Loose objects on upper storeys of houses rattled and hanging objects swung north-south. The shock caused cracks in the walls of old and dilapidated buildings.

BHILSA DISTRICT.

Bhilsa.

Dattatraya Sridhar Datar.—Duration 120 seconds. Two consecutive shocks followed by a creaking sound of the walls. The whole house appeared to be pushed as it were from below. Corrugated galvanised iron sheets, slabs, etc., on the roof and doors and windows rattled. Persons at rest felt the shock, which caused hanging objects to swing.

F. Essai, P. W. I., G. I. P. R.—One shock lasting about 180 seconds. Doors and windows rattled, hanging objects swung N. E.—S. W. Some walls were cracked. A stack of cast iron chairs fell towards the west.

Central India.

Sitamau State.

Sitamau.

Sitamau Darbar.—A slight shock.

Dewas State.

M. V. Deolekar, Meteorological Observer.—One shock for three seconds. It was felt by persons at rest, and caused doors and windows to rattle. Hanging objects swung and the observer's seat moved.

R. J. Mankar, Offg. Political Member.—The shock lasted 60 seconds and was of slight intensity. It made doors and windows rattle.

Indore State.

Wazir-ud-Dowlah Rai Bahadur S. M. Bhapna, C.I.E., Prime Minister to H. H. the Maharaja, Holkar, has supplied the following reports from the various *parganas* of the state.

Manasa.

One continuous shock for 120 seconds. There was a slight rattling of doors. A house in Alhed village was damaged.

Rampura.

Several shocks of which the first was strong and the rest mild. Duration 180 seconds. The shocks were felt by persons at rest, and the direction appeared to be east-west. Doors rattled and a house was cracked.

Bhanpura.

Walls in the second storeys of some houses were cracked.

Garot.

Three shocks for 180 seconds. A sound like the rustling of leaves was heard before the shock. Doors rattled. The direction of the shocks was N. E. –S. W.

Sunel.

Four shocks for about 120 seconds. Direction north-south. Doors rattled.

Zirapur.

One shock for ten seconds. Doors rattled. Direction of the shock north—south.

Mehidpur.

One shock for eight seconds felt by all except those who were walking. Loose objects rattled and seemed to move north-south. A few cracks in some houses were reported.

Tarana.

Two slight shocks lasting about 120 seconds and were felt on the second storey of houses. Loose objects rattled and seemed to move north-south.

Kannod.

One slight shock for four seconds. Doors and loose objects rattled.

Khategaon.

One slight shock.

Kantaphor.

One slight shock for four seconds. Direction of the shock east-west. Doors and windows rattled.

KHILCHIPUR STATE.

Khilchipur.

Indar Singh.—One big shock followed by two tremors. Duration 120-180 seconds. The shock was felt by persons at rest. Doors and windows rattled and hanging objects swung.

RAJGARH STATE.

Rajgarh.

The Diwan, Rajgarh State.—One shock preceded by a rolling sound and which continued until 30 seconds after the shock had ceased. The shock was sufficiently strong to awaken a boy who was asleep. Doors and windows rattled and hanging objects swung north-south.

NARSINGHGARH STATE.

Narsinghgarh.

The Diwan, Narsinghgarh State.—One slight shock lasting about 60 seconds.

BHOPAL STATE.

Sehore.

W. E. Essai, G. I. P. R.—One shock for 30 seconds. The roof of the office rattled.

Bhopal.

Superintendent, Meteorological Station.—The observations were made at the Military Club bungalow on a hill-side at an elevation of 1,800 feet. One continuous vibration lasting 120 seconds was felt. Doors and windows rattled and hanging objects swung. There were some plaster cracks on the walls of the bungalow. The ornamental pillars on the roof vibrated rapidly and wireless poles swayed.

R. H. Heaps, G. I. P. R.—Two or three shocks for 180 seconds. At first his seat moved slightly, then the roof creaked and the verandah moved noticeably and doors were shaking. Glasses on a side table were shaking steadily. Ceiling fans and lights swung. The movement was very noticeable on the first floor of the Imperial Bank (a two-storey building), fans and hanging lights swung in a large circle and a lady felt sea-sick.

Barkhera.

W. Y. Zincke, G. I. P. R.—One continuous shock for 180 seconds. Doors and windows rattled and some hanging objects oscillated.

Rewa State.

Umaria.

Meteorological Observer.—One continuous shock of moderate intensity for 300 seconds. Doors and windows rattled, hanging objects swung and the observer's seat moved. One wall of the local school building was cracked.

A. R. Roy, Burhar Colliery (81° 35′ : 23° 11′), *Dhanpuri. P. O.*—Time, 14·15-14·18 hours. One shock which commenced gently, rose to a maximum after 60 seconds and diminished in intensity after 120 seconds. A noise as of an approaching train was heard just before the shock. A brick and cement retaining wall, about 16 feet high, was cracked from top to bottom.

Central Provinces.

Narsinghpur district.

Narsinghpur.

Meteorological Observer.—Two shocks at intervals of five minutes. Chairs, tables and other objects were shaking. Some loose objects fell down.

Jubbulpore district.

Murwara.

M. I. Ansari, Tahsildar.—One shock. Doors and windows rattled, a *punkah* swung east-west and his chair was shaken.

Sihora.

Tahsildar.—One shock was felt by persons at rest, doors rattled and hanging objects swung east-west. A peculiar sound like that of an aeroplane was heard.

Patan.

Naib Tahsildar.—Two shocks which were felt by persons at rest. Doors rattled and hanging objects swung north-south. The observer's seat moved and walls of buildings were cracked in many cases.

Deori.

Station Master, G. I. P. R.—One moderate and continuous shock lasting 180 seconds. It was preceded by a thundering noise after which everything started to shake. Hanging objects swung N. E.– S. W., the observer's seat moved and loose objects were thrown towards the north-east. A few cracks appeared in the 3rd class waiting room.

Jubbulpore.

Subdivisional Officer, Jubbulpore.—The earthquake was felt in general, doors rattled, hanging objects swung and the observer's seat moved. The District Court buildings were slightly cracked.

S. M. A. Butt, Assistant Engineer, Headquarters subdivision.—One shock was felt by many people and caused doors and windows to rattle. Walls of some buildings were cracked.

L. C. Kapoor, Assistant Engineer, Roads subdivision.—Three shocks preceded by a rumbling noise.

Garrison Engineer.—Two shocks felt by persons at rest. Hanging objects swung and the observer's seat moved.

NIMAR DISTRICT.

Piplani.

G. Singh, Booking clerk, G. I. P. R.—Two mild shocks at 14·20 hours. Hanging objects swung east-west and loose objects were thrown either east or west.

HOSHANGABAD DISTRICT.

Pachmarhi.

Meteorological Observer.—One shock for 120 seconds. A sound like that of a railway train approaching a station or of a motor car at speed was heard during the shock, which was felt by persons at rest. Doors rattled, hanging objects swung and the observer's seat was shaken.

Sohagpur.

Tahsildar.—One shock felt by persons at rest. Doors rattled, a *punkah* moved east-west but the observer's seat moved north-south. Two stone pillars supporting the roof of the verandah moved half an inch.

Gadarwara.

P. G. Bruce, Deputy Commissioner.—Two shocks felt by persons at rest. The *punkah* moved north-south, trees moved as if there were a slight breeze although none was felt. A motor car facing south-east moved backwards and forwards.

Gadarvada.

District Commercial Inspector, G. I. P. R.—Several shocks, causing a sense of giddiness to some people who felt it difficult to stand. Doors, windows, pots, C. I. sheets on roof, etc., rattled. Some loose objects fell and the observer's seat was shaken.

Hoshangabad.

S. Bhagwat.—Two shocks, the second being stronger than the first, were felt by persons at rest. Doors rattled, hanging objects swung and the observer's seat moved.

According to Mr. P. G. Bruce, the Deputy Commissioner, Hoshangabad district, a crack in the Church wall widened and a door frame in the D. C.'s bungalow sank about an inch.

Itarsi.

B. F. Peters.—Several shocks lasting 180-240 seconds. Doors and windows rattled and the observer's seat was slightly moved.

V. Welsh.—Two shocks for 120 seconds, the first shock was strong and the second one weak. Doors rattled and hanging objects swung east-west. The shocks were felt by persons at rest.

R. A. Arathoon.—Continuous shocks lasting 120-420 seconds. At first a rocking motion and then a circular motion was felt. All the three wall clocks of the railway running room stopped.

Bhilakheri.

Stationmaster, G. I. P. R.—One slight shock for 240 seconds. Hanging objects swung.

Khutwansa.

Stationmaster, G. I. P. R.- Time 14·12—14·15 hours. One smart shock for 180 seconds, glasses of two lamps on the platform were smashed.

Dharamkundi.

Stationmaster, G. I. P. R.— Several strong shocks in quick succession lasting about 180 seconds. The block instruments were giving very slight strikes.

Banapura.

Stationmaster, G. I. P. R.—One continuous but slight shock for 180 seconds. Hanging objects swung north-south.

Sconi Malwa.

Stationmaster.—Two shocks separated by an interval of about one minute, the second shock was the stronger of the two.

Pagdhal.

Stationmaster, G. I. P. R.—One shock for 180 seconds between 14·15 and 14·18 hours.

Chhidgaon.

Damodar, Booking clerk, G. I. P. R.—One shock at 14·15 hours lasting 180 seconds. A noise like that of a running train or a motor lorry was heard during the shock, which was felt by persons at rest. Some loose objects fell.

Timurni.

Assistant Stationmaster, G. I. P. R.—Two light shocks for two seconds at 14·20 hours. Doors and windows rattled a little.

Charkhera.

Stationmaster, G. I. P. R.—One shock for 60 seconds. The observer's seat was shaken.

Harda.

Tahsildar.—Two shocks felt by persons at rest, doors and windows rattled and hanging objects swung. The observer's seat moved.

Stationmaster, G. I. P. R.—One shock for five seconds. Doors and windows rattled.

Palasner.

Stationmaster, G. I. P. R.—Two slight shocks at 14·17 hours.

Bhiringi.

Stationmaster, G. I. P. R.—Two shocks at an interval of five minutes, each shock lasting for a second or two.

Khirkiya.

Stationmaster, G. I. P. R.—One slight shock for 150 seconds. Hanging objects swung very slightly.

CHHINDWARA DISTRICT.

Amarwara.

M. Hasan.—One shock preceded by a sound like that of a motor car. The sound lasted throughout the shock, which was felt by persons at rest and caused doors to rattle.

Junnordeo.

P. H. Kitchen, Ghorawary Colliery.—One shock felt by persons at rest. Doors rattled and two cracks appeared in the walls of the Manager's bungalow.

Ghagri Bercui Colliery.—One shock felt by persons at rest.

Iklehra.

R. N. Khare, G. I. P. R.—One slight shock for 300 seconds. It moved the observer's seat.

Parasia.

W. J. B. Reynolds, Chandametta Bungalow.—One shock increasing in intensity and giving place to a vibration towards the end. A tilting sensation was felt. Loose objects rattled and the bungalow was cracked.

Chandametta.

D. W. Bell.—Four shocks causing roof and ceiling of the bungalow to rattle. A *punkah* swung north-south and crockery and glasses vibrated.

Barkuhi.

S. Mazheruddin, East Barkuhi Colliery.—One shock. Doors and windows rattled, hanging objects swung east-west and the whole place rocked.

Another report from Barkuhi states that three days after the earthquake there were severe falls of roof in two of the coal mines.

Chhindwara.

No report is available from Chhindwara but Mr. A. E. Turner, District Superintendent of Police, Chhindwara, reported that water in a hot sulphur spring at V. Anhoni, near Mahuljhir on the Hoshangabad border (23° 35′ : 78° 36′) became hotter than usual and bubbled vigorously with sulphur. The level of the water was about 18 inches higher than usual at the time of the earthquake and was six inches higher than normal after about ten minutes. It then settled down to its original level.

Sausar.

S. B. Shidhaya, Pleader.—One shock with a sound like that of a train passing. Doors and windows rattled, hanging objects swung and the observer's seat moved.

MANDLA DISTRICT.

Niwas.

Naib Tahsildar.—One continuous shock preceded by a sound like that of a motor car, coming from the north. It was felt by persons at rest and caused doors and windows to rattle.

Mandla.

Secretary, Municipal Committee.—One strong shock for 120 seconds during which a sound like that of a motor car was heard. Doors rattled, hanging objects swung north-south, the observer's seat moved and tiles on roof were thrown down. In some *pucca* buildings there were cracks up to ⅛th-inch wide.

Dindori.

Naib Tahsildar.—Two shocks preceded by a sound like that of a motor lorry. Doors rattled and hanging objects swung.

BILASPUR DISTRICT.

Katghora.

Tahsildar, Katghora.—Two shocks preceded by a noise like that of a heavy lorry. The replies to the questions are in conformity with isoseismal V.

Mungeli.

Jagat Ram.—One continuous shock with a sound like that of an approaching train. Most persons felt the shock, which caused doors and windows to rattle. Hanging objects swung east-west. Hair cracks appeared in some walls including the strong room of the Treasury. Some persons felt giddy.

Bilaspur.

Kishori Lal, Tahsildar.—The shock was not felt by persons moving on cycles or carriages. A few *pucca* buildings were craked slightly.

L. F. D. O'Dea, Railway Station Settlement.—Two shocks separated by an interval of 30 seconds. Persons asleep felt as if the bed were pushed from below. Houses swayed slightly in a north-south direction. A clock on the western wall stopped, that on the northern wall did not stop. Hanging flower pots swayed violently north-south. Tiles of roof made a rubbing noise and doors, windows and bolts rattled.

Janjgir.

Tahsildar.—Two shocks in succession accompanied by sounds like that of an aeroplane or motor car in motion. Persons resting felt the shocks, doors and windows rattled and the observer's seat moved.

SEONI DISTRICT.

Seoni.

E. S. Hyde, Subdivisional Officer.—Two shocks with a rumbling sound like that of a car or an aeroplane. Doors rattled and hanging objects swung east-west. His seat was shaken.

BALAGHAT DISTRICT.

Waraseoni.

R. K. Tiwari, Tahsildar.—One shock preceded by a noise like that of a car approaching. Many people felt the shock and doors and windows rattled.

Nagpur district.

Ramtek.

Tahsildar.—One feeble shock. Doors and windows rattled, hanging objects swung both east-west and north-south. Some of the country tiles fell from the roof of houses and the shock was more felt in double storey buildings than elsewhere. No shock was reported from the hill areas of the *tahsil.*

Bhandara district.

Tirora.

Range·Officer.—Two shocks separated by an interval of 120 seconds. Doors rattled, the observer's seat shook and some tiles fell.

Eastern States.

Gangpur State.

Sundargarh.

H. D. Christian, Superintendent, Gangpur State.—One continuous tremor for 180 seconds. A dull roar as of a car approaching and passing was heard. The shock was felt by persons at rest. A loose door rattled, water and ink quivered distinctly. Hanging objects swung east-west but the observer's seat did not move. Slight cracks appeared only in large buildings with terraced roofs.

Bonai State.

Bonaigarh.

A. J. Ollenbach, Dewan, Bonai State.—He felt one continuous shock lasting about 180 seconds. During the shock a continuous rattling noise like that of a passing train was heard. The shock was strong enough to waken people from sleep; doors and windows and loose articles rattled violently, and water in tubs spilled out. Hanging objects swung east-west. Two *kutcha* walls at Bank, 25 miles north of the town, were reported to have been cracked.

Bamra State.

Deogarh.

H. McPherson, Superintendent, Bamra State.—He felt one shock at 14·15 hours, lasting about 200 seconds. Immediately before the shock a rumbling sound resembling "the approach of a motor car in a strong wind" was heard. The shock was felt by persons at rest, doors and windows rattled, hanging objects swung slightly in a N. E.—S. W. direction and his seat vibrated slightly.

Rairakhol State.

Rairakhol.

P. Datta, Medical Officer.—He felt two shocks lasting about one minute. The second shock was the stronger of the two. Doors and windows slightly rattled and the tiles of the sloping roof of his bungalow fell. The observer's seat moved.

Talcher State.

Talcher.

R. B. Misra, Private Secretary's Office, Talcher Raj.—One shock for 120 seconds. It was felt by persons at rest, doors and windows rattled, hanging objects swung N. E.—S. W. and walls of buildings were cracked.

Pal-Lahara State.

Pal-Lahara.

D. Tripathi, Forest Ranger.—He was standing out of doors and recorded two shocks at an interval of a second or two. Before and during the shocks a rumbling noise, like that of a motor car in motion, was heard. The shock was felt by persons at rest, doors and windows rattled and hanging objects moved freely from N. E.—S. W. Walls of some buildings were cracked.

Keonjhar State.

Keonjhargarh.

State Engineer.—One shock, lasting 120 seconds, was felt at 14·15 hours. A low rumbling noise, like that of a motor car in motion at a distance, was heard during the shock, which was felt by persons at rest. Doors and windows rattled and his seat was shaken.

Saraikela State.

Saraikela.

Rajah's Personal Secretary.—Duration 270 seconds. The observer was standing and heard a sound like that of a railway engine. Doors, windows and other loose objects rattled and hanging objects swung north-south.

Kharsawan State.

Kharsawan.

Rajanikanta Sarangi.—Duration 360 seconds. Two shocks were felt and a rumbling noise, like that of a motor on starting, was heard before and during the shocks. Many persons felt the shocks, doors and windows rattled and the observer's seat moved. Loose objects fell both east and west. Walls of buildings were slightly cracked and a new building at the palace was slightly cracked.

Mayurbhanj State.

Baripada.

H. A. Gubbay, Retired Chief Engineer, P. W. D.—He felt two jerky shocks and some tremors lasting about 150 seconds. Doors and windows rattled and the terraced roof cracked and squeaked. Electric ceiling lights and fans swung freely east-west.

Gurumahisani.

Deputy Superintendent of Ore Mines and Quarries, Tata Iron and Steel Co., Ltd.—The observer was at first indoors and then out of doors. Duration 180 seconds with a break of 20-30 seconds. Two shocks were felt of which the second was stronger than the first. A sound, as if a strong wind were blowing, was heard

inside the building; outside, a noise like that of a motor car running at a distance was heard. The first shock caused ink spots on the paper on which he was writing and then he felt as if he were shivering with an attack of slight ague. Out of doors the observer felt waves passing under his feet and felt slightly giddy. Floors of buildings and sides of adjoining drains were slightly cracked and old cracks widened. Windows, doors, mosquito poles of the bed, etc., rattled but no loose objects were thrown. Judging from moving tree tops the direction of movement was from south to north. Rattling of window panes gave nearly five ticks per second. Cracks in floors, although in all directions, were more pronounced on the southern and eastern sides of the building.

NILGIRI STATE.

Nilgiri.

Dewan, Nilgiri State.—He felt one continuous shock for 240 seconds. The shock was felt by persons at rest. Doors and windows rattled, and hanging objects swung east-west.

Orissa.

BALASORE DISTRICT.

Jaleswar.

Sub-Inspector of Police, Jaleswar.—One shock for 120 seconds. The observer's seat was shaken.

Remuna.

S. Tripatty, Remuna Police Station.—One shock for 150 seconds. His chair moved and hanging objects swung north-south.

Balasore.

B. Sen Gupta, Civil Surgeon.—A continuous mild shock for 240 seconds. It was preceded by a rumbling sound and was felt by persons at rest. Doors and windows rattled, hanging objects swung north-south and the observer's seat moved.

Office Superintendent, Collectorate.—One shock for 240 seconds. At first the movement was north-south and then east-west, trees swayed east-west. Doors rattled and the observer's seat moved.

Sub-Inspector of Police.—One shock for 120 seconds. Trees swayed north-south and some bricks fell from a cracked building.

Bengal.

MIDNAPORE DISTRICT.

Jhargram.

K. Ahmed, Subdivisional Officer, Jhargram.—Two shocks felt by most people. Doors and windows rattled, hanging objects swung, loose objects were thrown down and some of the buildings were slightly cracked.

Hijli.

B. N. Bose, Circle Officer.—Three undulatory shocks. Doors rattled, hanging objects swung and a few walls were cracked.

Midnapore.

Circle Officer, Sadar.—Some people at Midnapore felt three shocks for 30 seconds. Doors rattled and hanging objects swung.

Pingla.

S. K. Mitter, Circle Officer, Pingla.—One shock for 30 seconds. Doors and windows rattled and hanging objects swung.

Tamluk.

Subdivisional Officer, Tamluk.—He was at Mahisadal in Midnapore district and felt one continuous shock with an east-west movement at first and afterwards it changed its direction. Slight cracks appeared in buildings.

A. N. Daud, Sub-Deputy Magistrate, Tamluk.—One continuous tremor felt by all. Doors rattled, hanging objects swung, loose objects fell and his seat moved up and down slightly. Trees swayed from side to side and some buildings were slightly cracked.

Dantan.

A. C. Mazumdar, Circle Officer.—Two shocks preceded by a 'mild groaning' sound. Doors and windows rattled, hanging objects swung, and the observer's seat moved.

Contai.

S. B. Malakar.—One mild shock was felt.

24-PARGANAS.

Bishnupur.

S. K. Chatterjee, President, Union Board.—One continuous shock varying in intensity. Doors and windows rattled, hanging objects swung east-west, the observer's seat moved and walls of buildings were slightly cracked.

Diamond Harbour.

R. K. Roy, S. D. O., Diamond Harbour.—One continuous shock increasing in intensity and culminating in a severe shock lasting a few seconds. Most people felt the shock, hanging objects swung, doors and windows rattled and the wall of one building was slightly cracked.

BAKARGANJ DISTRICT.

Patuakhali.

B. Das Gupta.—Two shocks, for 180 seconds, separated by an interval of 15-20 seconds. The shocks were felt by persons at rest, hanging objects swung and the observer's seat moved.

Khepupara.

Syed Abdul Ali, Sub-Deputy Magistrate.—Two shocks in quick succession. Doors and windows rattled slightly and hanging objects swung N. W.—S. E.

Sadar Subdivision, South.

Meteorological Observer.—Several shocks coming from a westerly direction. Doors rattled, hanging objects swung and the observer's seat moved.

Noakhali district.

Lakshmipur.

S. A. Khan, Circle Officer.—Three shocks for 240 seconds. Doors rattled, hanging objects swung east-west and the observer's seat moved.

Noakhali.

J. C. Majumdar, Meteorological Observer.—Four shocks each lasting 15 seconds, hanging objects swung north-south and the observor's seat moved slightly.

Hatia.

Officer in Charge, Police Station.—Three shocks felt by persons at rest. Duration 180 seconds. Doors and windows rattled, hanging objects swung and the observor's seat moved.

General (Noakhali District).—Reports from other parts of Noakhali district show that, in general, two to three shocks of slight intensity were felt by persons at rest. Hanging objects swung north-south generally. Doors and windows rattled and no damage was caused.

Dacca district.

Narayanganj.

Rashid Khan.—Four shocks felt by persons at rest. Doors and windows rattled and hanging objects swung.

Tippera district.

Comilla.

P. N. Mukerjee, Subdivisional Officer, Sadar.—Three moderate shocks for 165 seconds felt by persons at rest. Hanging objects swung W. N. W.—E. S. E. The waves were rather long.

Assam.

Goalpara district.

General.—Reports from villages in Goalpara district show that the maximum duration of the shock was 180 seconds. Most people recorded one shock, which was strong enough to be felt by persons at rest, to make hanging objects swing and to cause doors and windows to rattle. In one or two instances a sound like that of a motor car in motion was heard before the shock.

Goshaingaon.

T. Borah, Sub Inspector of Police.—Duration 180 seconds. The shock was felt by persons at rest, it caused doors and windows to rattle and hanging objects to oscillate.

Kokrajhar.

M. Y. Ali, Sub Inspector of Police.—He felt one shock and heard some sound. Hanging objects swung and his seat was moved.

North Salmara.

Officer in Charge, Police Station.—One shock for 30 seconds which rattled doors and windows, swung hanging objects and moved the observer's seat.

South Salmara.

Sub-Inspector of Police.—Three shocks lasting 150 seconds. Hanging objects swung and the observer's seat was moved.

Mankachar.

P. C. Bhowmik.—Duration 180 seconds. One continuous shock which began with a slight shaking and gradually became stronger, when he had to sit down. Hanging objects swung slightly and his seat was shaken.

KAMRUP DISTRICT.

Gauhati.

A. K. Bhuyan, Meteorological Observatory.—One continuous shock of moderate intensity lasting about 225 seconds was felt at 14.19 (I. S. T.). The replies to the questions are in conformity with isoseismal V.

H. M. Prichard, Deputy Commissioner, Kamrup district.—He was standing on a village path talking when the earthquake began. He walked some 200 yards down the path and then watched a shallow pool in which water oscillated first north-south and then east-west. The shock was continuous but not violent and could not have lasted more than six minutes. It was felt by persons at rest and made doors, windows and loose objects rattle and hanging objects swing.

NOWGONG DISTRICT.

General.—One shock the maximum duration of which was felt in Nowgong district up to 180 seconds and in some cases as low as 50 seconds. The shock was strong enough to be felt by persons at rest and to make doors, windows or loose objects rattle, to swing hanging objects and to move observers' seats. One person felt the movement in a N. W.- S. E. direction and another observer felt an east-west movement.

Nowgong.

H. Rahman.—Duration 120 seconds. He was lying on bed and felt one continuous shock which caused doors and windows to rattle. Hanging objects swung east west. His bed was moved.

Salona.

P. N. Chakravarty, Salona Observatory.—Duration 180 seconds. Continuous, slow but severe vibrations which were felt by persons at rest. Doors, windows and loose objects rattled and floors creaked. Hanging objects swung and loose objects were thrown down.

SIBSAGAR DISTRICT.

Titabar.

D. S. Hamilton Hunt.—Duration 240 seconds. The quake resembled a long succession of waves gradually increasing until midway of the duration when a decided bump was felt and after which the waves gradually decreased. Doors and windows rattled. Hanging flower pots, fans and lights began to swing definitely east-west. Photos were thrown down and the observer's seat moved from side to side. Some walls in the bungalow and factory buildings were slightly cracked.

Lakhimpur district.

North Lakhimpur.

Subdivisional Officer, N. Lakhimpur.—Duration 180-240 seconds. One continuous but slight vibration of varying intensity felt by persons at rest. Doors and windows rattled, hanging objects swung and some loose objects fell. Slight plaster cracks in high buildings.

Dibrugarh.

S. N. Sen.—Two shocks were felt by persons at rest and which caused hanging objects to swing. The observer's seat was moved.

Garo Hills.

Tura.

W. Shaw, Deputy Commissioner, Garo Hills.—He felt one continuous shock of varying intensity for 150 seconds. A rumbling noise accompanied the shock. Doors and windows rattled, hanging objects swung and walls of some buildings were cracked.

Khasi Hills.

Shillong.

K. Cantlie, Deputy Commissioner, Khasi and Jaintia Hills.—A mild shock was felt for 30 seconds, but slight tremors continued for a longer period.

E. A. Elkington, Meteorological Observer.—14.15 (I. S. T.). A series of tremors decreasing and increasing in intensity and lasting about 200 seconds. Doors and windows slightly rattled and telegraph wires swayed.

Cherrapunji.

A. C. Bhattacharji, Meteorological Observer—14.16 (I. S. T.). Three shocks lasting ten seconds were felt.

Sylhet district.

Sunamganj.

L. M. Shome, Subdivisional Officer, Sunamganj.— He was sitting in court and felt one shock lasting 190 seconds. Doors, windows and loose objects rattled and hanging objects swung east-west. Some loose objects were thrown down.

Sylhet.

C. S. Gunning, Deputy Commissioner, Sylhet district.—A prolonged quivering shock lasted about 120 seconds. Loose objects rattled and hanging objects swung in an east-west direction. The shock moved the observer's seat and was felt by persons at rest.

Habiganj.

D. Sarma, Subdivisional Officer, Habiganj.—He felt a continuous, oscillatory shock for about 120 seconds. It was strong enough to make doors and windows rattle and was felt by persons at rest. The shock moved the observer's seat and caused hanging objects to swing.

Karimganj.

S. Goswami, Subdivisional Officer, Karimganj.—He was standing out of doors and felt two major shocks, which were preceded by a series of slight tremors. The shocks caused doors and windows to rattle and hanging objects to swing west-east.

Badarpur Ghat.

P. Evans, Badarpur Ghat (24° 52′ : 92° 36′).—One continuous slight trembling, varying in frequency and lasting 50 seconds. The shock was felt by some (but not all) persons at rest and was strong enough to cause hanging lamps and *punkahs* swing. The direction of movement appeared to be N. W.—S. E.

Kulaura.

K. W. P. Marar, Subdivisional Officer, South Sylhet.—He felt the shock for 30 seconds at Kulaura, while lying on a bed. The shock caused doors and windows to rattle and hanging objects to swing.

CACHAR DISTRICT.

Silchar.

Capt. R. A. Haythornthwaite, Civil Surgeon.—He felt a continuous shock lasting about 175 seconds. Hanging objects swung freely. Trees and buildings rocked visibly in an east-west direction.

Maulvi Ayub R. Majmadar, Extra Assistant Commissioner.—A mild shock was felt for 180 seconds. Doors and windows rattled and hanging objects swung.

Nasimpur.

G. F. Wilson.—A series of tremors lasting from 90-120 seconds and causing hanging lamps and fans to swing. The direction of movement was between N. N. W.—S. S. E. to N. W.—S. E.

Bhutan.

Raja S. T. Dorji, Agent to the Maharajah of Bhutan, writing of the shock at Bhutan, stated that only one shock was felt at about 2.31 p. m. The shock lasted about 180 seconds and was felt by persons at rest. Doors and windows rattled, hanging objects swung but no damage appeared to have been caused.

Tibet.

GYANTSE.

Capt. P. C. Hailey, British Trade Agent, Gyantse, Tibet.—He was sitting indoors and felt only one shock for 20 seconds at about 2.35 p. m. A strong dust storm was going on at that time and no unusual sound was heard. The shock could be felt by persons at rest, doors, windows and loose objects rattled slightly and a few panes of glass were broken. Hanging objects swung slightly but the shock was not severe enough to throw down loose objects. One or two slight cracks, mostly in mud plaster, were noticed.

Capt. Hailey also reported that a shock of slightly stronger intensity was felt at Shigatse at about the same time.

CHAPTER XXVII.

ISOSEISMAL IV.

It has been found possible to draw an isoseismal within which the intensity reached IV on the Mercalli scale, and to distinguish an outer area of lower intensity, III and II. Naturally, along the border of these zones there are many irregularities, for which due allowance must be made.

As within isoseismal IV at the mouth of the Mahanadi, there is also, within isoseismal II-III, an area of increased intensity IV at the mouths of the Godavari and Kistna rivers.

Kashmir.

Srinagar.

Meteorological Observer, Government of Jammu and Kashmir.—One moderate shock for two seconds, 14.20 (I. S. T.—Madras time). Persons at rest felt the shock. The shock was strong enough to rattle doors and windows, to make hanging objects swing and to shake the observer's seat.

Punjab.

HOSHIARPUR DISTRICT.

Hoshiarpur.

Khan Bahadur S. B. Hussain, Deputy Commissioner.—One mild shock causing doors and windows to rattle slightly.

KAPURTHALA STATE.

Kapurthala.

Diwan Sir Abdul Hamid, Chief Minister.—Two shocks for two seconds, felt by persons at rest. Doors and windows rattled slightly. Hanging objects swung east-west. The observer's seat moved.

JULLUNDUR DISTRICT.

Jullundur.

J. A. Ferguson, O.B.E., Commissioner, Jullundur Division.—Two shocks, each consisting of a number of vibrations. Total duration of shocks less than 30 seconds. The observer's revolving chair rocked from west to east. Some woodwork in the room began to make a ticking noise at intervals of half a second. The shock was not felt by all. Electric light swung slightly anti-clockwise, fan shaft rocked north-south.

Tahsildar.—Three shocks for 30 seconds separated by an interval of ten seconds each. The observer felt them whilst sitting on a chair.

NABHA STATE.

Nabha.

Rai Bahadur Diwan Gyan Nath, C.I.E.—Two shocks for a few seconds. Persons at rest felt the shocks, which caused doors and windows to rattle. Hanging objects swung and some buildings were slightly cracked.

PATIALA STATE.

Patiala.

Nazim, Barnata.—Two or three shocks. Felt by all who were sitting on chairs in the compound of Sardar Bachhtar Singh Sahib's house at Patiala.

New Patiala.

Nazim, Patiala.—Two or three slight shocks, doors and windows rattled, hanging objects swung and the observer's seat moved.

Bhawanigarh.

Tahsildar.—15-20 shocks were felt in the upper storey of his house. Doors and windows rattled and his seat moved a little.

Kanda Ghat.

Tahsildar.—Two or three very slight shocks.

HISSAR DISTRICT.

Hissar.

Superintendent, Government Cattle Farm.—Three shocks at short intervals of about a second between the first and the second and about 60 seconds between the second and the third. Doors and windows rattled.

SIMLA DISTRICT.

Simla.

Dr. D. F. Michael, Archdale, Simla.—One continuous shock for 40-50 seconds. Sliding glazed windows shook and rattled. Ceiling lights swayed and the chair on which the observer was seated trembled slightly.

E. A. R. Eustace.—Two shocks for ten seconds, felt by persons at rest. Doors and windows rattled, hanging objects swung and the observer's seat moved.

Subathu.

Mrs. A. H. Watson.—One continuous tremor. The observer, who was resting, awake in bed, felt as if some one were under the bed and shaking it up and down steadily for 30 seconds. Doors and windows rattled and the floor creaked.

AMBALA DISTRICT.

Ambala.

Faiz Ali Khan, Tahsildar.—Two shocks at an interval of half a second. Doors and windows slightly rattled.

Ambala Cantonment.

W. D. McDonald, E.A.C.—One very slight shock. The dais on which his chair rested shook a little.

B. Deoki Nandan.—Two slight shocks for three seconds and separated by an interval of one second. Chair and table moved slightly.

Naraingarh.

Dalmir Singh.—Three shocks at intervals of two seconds. Total duration five seconds. Doors and windows rattled and the observer's seat moved.

Jagadhri.

B. Ahmad, Sub-Judge.—Two shocks for ten seconds having an interval of two seconds. Hanging objects swung north-south. His seat moved a little.

L. J. Prasad Garga, Pleader.—One moderate shock for five seconds. Hanging objects swung and his seat moved.

JIND STATE.

Jind.

Hari Dass, Medical Officer.—Three shocks for 180 seconds, felt by persons at rest. Hanging objects swung east-west and the observer's seat moved.

Sangrur.

Ranjit Singh, Sub-Assistant Surgeon.—Two shocks for sixty seconds, felt by persons at rest. The observer's seat moved and some loose objects were thrown down.

Safidon.

Sis Ram.—Three shocks felt by persons at rest. Doors and windows rattled and hanging objects swung N. W.—S. E.

Charkhi Dadri.

Bhopal Dev, Sub-Assistant Surgeon.—One shock strong enough for 60 seconds. Total duration of the shock was 125 seconds. Persons at rest felt the shock, doors and windows rattled and hanging objects swung north-south. The observer's seat moved and loose objects were thrown to the south. Walls of some buildings were cracked.

Rajputana.

BIKANER STATE.

Bikaner.

S. Vias.—Two mild shocks for 90 seconds, with an interval of 50 seconds. Unusual cracking sound was heard during the shocks. The observer's chair received slight jerks.

JODHPUR STATE.

Didwana.

The Hakim, Didwana.—Two almost continuous shocks for 80 seconds. They were felt by persons at rest, doors and windows rattled and the observer's seat moved slightly.

Nagaur.

The Hakim, Nagaur.—Two or three shocks for 90 seconds. Persons at rest felt the shocks, hanging objects swung north-south and the observer's seat moved.

Parbatsar.

The Hakim, Parbatsar.—One shock for 60 seconds. Windows rattled.

Merta.

The Hakim, Merta.—One shock for 60 seconds. The observer's seat moved slightly.

Jodhpur.

J. S. Gaur, Meteorological Observer, Jodhpur.—Three major shocks followed by minor ones, all lasting 25-30 seconds. Persons at rest felt the shocks, doors rattled, hanging objects swung and the observer's seat moved.

Bilara.

The Hakim, Bilara.—One shock for 30 seconds felt by many persons. Doors and windows rattled, and hanging objects swung east-west.

Jaitaran.

The Hakim, Jaitaran.—Three shocks for 120 seconds, separated by two intervals. Doors rattled and hanging objects swung east-west.

Sojat (isoseismal III ?).

The Hakim, Sojat.—One slight shock for ten seconds.

Pali.

The Hakim, Pali.—Four shocks for 32 seconds. Persons at rest felt the shocks, doors rattled, hanging objects swung north-south and the observer's seat moved slightly.

Jalor.

The Hakim, Jalor.—One shock for 60 seconds. A sound as of a running motor car was heard before and during the shock. Some persons felt the shock and hanging objects swung.

Desuri.

The Hakim, Desuri.—One shock for 25 seconds, a sound resembling that of the firing of a gun was heard after the shock. Windows and doors rattled.

Bali (isoseismal III ?).

The Headmaster, D. V. M. School.—One shock for ten seconds. A buzzing sound as of a motor car was heard before the shock, which was felt by persons at rest.

Jaswantpura (isoseismal III ?).

The Hakim, Jaswantpura.—Persons at rest felt a slight shock accompanied by a slight rumbling.

MEWAR STATE.

Udaipur.

Musahib Ali.—A slight shock lasting for about 30 seconds. Walls of a few *kutcha* huts in Shakargar, Jahazpur district, were cracked.

PARTABGARH STATE.

Partabgarh.

A. Aziz.—One continuous shock for about 120 seconds. Loose doors rattled. The intensity of the shock was slight.

Central India.

Mr. K. S. Fitze, C.I.E., Political Agent in the Southern States of Central India and Malwa, has kindly supplied the following reports from the different States:—

PIPLODA STATE.

Piploda.

One shock for 120 seconds felt by persons at rest. Doors and windows rattled, hanging objects swung east-west. Loose objects fell and the walls of the old palace were cracked.

JAORA STATE.

Jaora.

One shock, very slight at the beginning but increasing in intensity towards the end. Duration 120 seconds. Doors and windows in the second floor of two-storey buildings rattled. A slight rolling motion was felt.

SAILANA STATE.

Sailana.

Three shocks in all for 159 seconds. The second shock was quite distinct and the third mild. A pendulum-like movement was felt. Doors, windows and corrugated iron roofs rattled. Some persons were roused from sleep. Hanging objects swung and some loose objects fell.

Ratlam Darbar.

Two or three mild shocks making loose doors rattle and hanging objects swing.

JHABUA STATE.

Jhabua.

Two shocks for four seconds. The quake was felt by persons in the upper storey of a house. Doors and loose objects rattled slightly. Hanging objects swung north-south.

Dhar Darbar (isoseismal III ?).

A slight and insignificant shock was felt at Dhar and Dharampuri at about 2.16 p. m. and 2.30 p. m. respectively.

Ali Rajpur State.

Ali Rajpur.

One shock for 4-5 seconds. Some persons heard a sound like that of a passing motor lorry. Doors, windows, corrugated iron roofing rattled. Loose objects fell from shelves.

Barwani State.

Barwani.

One shock for 10-15 seconds. The shock was observed by persons awake, those asleep did not feel the shock. Some loose objects rattled.

Indore State.

The following reports from various parganas of Indore State are kindly supplied by Wazir-ud-Dowlah and Rai Bahadur S. M. Bhapna, C.I.E., Prime Minister to H. H. the Maharaja Holkar :—

Petlawad.

One slight shock for 120 seconds. It was accompanied by a noise. Loose objects rattled.

Depalpur.

One shock only felt by persons at rest, especially those sitting in the second storey of houses. Duration, five seconds. Loose objects rattled and hanging objects swung north-south.

Sawer.

One shock for seven seconds.

Indore.

One shock for 90 seconds felt by persons at rest.

The Meteorological Observer of Indore reports two shocks for 90 seconds with an interval of 30 seconds. The shocks were felt by persons at rest, especially by those in the second storey of houses. Doors and windows rattled and hanging objects swung.

Mhow.

One slight shock for two seconds. Loose objects rattled. The shock was felt by persons in the second storey of houses.

Nisarpur.

One slight shock for four seconds felt by persons at rest. Doors rattled.

Maheswar.

One slight shock for 30 seconds felt by persons at rest. Doors rattled.

Kasrawad.

One slight shock for ten seconds. A low thundering noise was heard as if coming from a distance. The shock was felt by persons in the second storey of houses.

Barwaha.

One slight shock for two seconds. It was felt by persons at rest. Doors rattled.

Bhikangaon.

Slight shocks of a second's duration were felt in seven villages of this pargana.

Khargon.

Two slight shocks for two seconds. Doors and windows rattled. The direction of the shock was north-south.

Hyderabad State (Deccan).

ADILABAD DISTRICT.

One slight shock was felt at Rajura for 60 seconds, at Sirpur for three or four seconds and at Asifabad for 30 seconds. Buildings vibrated in these places.

The First Taluqdar, Asifabad, was working in his office and felt his chair and table shaking at about 2.15 p. m. On enquiry he found that several people in the vicinity felt the shock, the motor car in the garage and the cots in the houses were also seen shaking and one man fell down. The earthquake lasted about 30 seconds.

Mr. Reporter, Customs Superintendent, Warangal, was at the P. W. D. Inspection Bungalow, opposite the Asifabad Railway station, and he felt a slight shock for 30 seconds about 2.25 p. m. The shock was also felt and noticed by his staff and the Railway Stationmaster.

Bhir district.

Four shocks were felt at Bhir for 60 seconds. The first and the third were severe and the others of slight intensity.

The First Taluqdar, Bhir, felt a slight shock.

Nizamabad district.

One shock was felt at Armur for one second and at Bodhan for two to three seconds. Some hanging objects swung.

Karimnagar district.

At Manthani village in Mahadeopur taluq three shocks were felt for 15-20 seconds. Hanging objects swung to and fro.

At Kishenraopet in Sultanabad one shock was felt for four seconds. Water in wells shook and made some noise.

At Karimnagar an extraordinary shock was reported to have been felt for about 120 seconds. People were terror stricken on this account.

Berar (C. P.).

AMRAOTI DISTRICT.

Chikalda.

J. C. Deshmukh.—One shock felt by persons at rest. Doors, windows and loose objects rattled.

Ellichpur.

N. L. Despande.—One shock was felt which caused many people to feel giddy. Doors and windows rattled, hanging objects swung north-south and the observer's

seat moved in the same direction. Loose objects fell in some places. People in the upper storey of a house felt the shock more than others.

Stationmaster, G. I. P. R.—One shock for five seconds.

Chamak.

Stationmaster, G. I. P. R.—Four or five shocks for 120 seconds. Hanging objects swung east-west.

Lehegaon.

D. Ranade.—Two shocks causing loose objects and tiles of roof to rattle. Hanging objects swung north-south.

Daryapur.

J. Ribeyro.—One continuous shock for 60 seconds. Doors rattled, hanging objects swung north-south. Observer's seat moved north-south. Some buildings were slightly cracked.

Amraoti.

C. L. M. McClenaghan.—One shock for 120 seconds felt by persons at rest. Doors and windows rattled.

Kurha.

T. Chandar.—One shock. Windows and chairs rattled. Tea cups and saucers on racks jingled.

Nandgaon Kazi.

K. M. Pande.—A light shock was felt. Some earthen pots fell and tin sheets from the roof came down.

General (Amraoti district).—Reports from other *taluqs* and *tahsils* in Amraoti district show that one to three light shocks were felt, mostly by persons at rest. Both north-south and east-west movements were recorded. Majority are in favour of a north-south movement. Doors and loose objects rattled and in some cases observers' seats were shaken. In Dhanor *taluq* tiles from roofs of some houses fell.

BULDANA DISTRICT.

Jalgaon.

R. D. Joshi, Naib Tahsildar.—One shock was felt. Hanging objects swung.

Malkapur.

R. B. Despande.—One continuous shock felt by persons sleeping on the second storey of houses. Doors and windows rattled and hanging objects swung east-west.

K. G. Mahajan.—Four or five shocks. Articles on a stool appeared to move in a north-south direction.

Nandura.

Stationmaster, G. I. P. R.—Six shocks for 60 seconds, felt by persons at rest. Hanging objects swung east-west.

Akola district.

Akot.

Tahsildar.—Three shocks for three seconds. Persons at rest felt the shocks. Hanging objects swung north-south.

Balapur.

Tahsildar.—Two shocks felt by persons at rest. Hanging objects swung north-south.

Akola.

District Judge.—Three shocks for 30 seconds. The shutters of a wall-almirah rattled. *Punkah* first swung north-south and then east-west. The observer's seat moved.

Tahsildar.—Two shocks for two seconds felt by persons at rest. Hanging objects swung north-south. Loose objects were thrown either north or south.

Inspector of Works, G. I. P. R.—One big shock for 15 seconds.

Murtazpur.

Tahsildar.—One shock felt by persons at rest.

Basim (isoseismal III ?).

Tahsildar.—Only a slight shaking for two seconds. Doors on the second floor of his house and loose articles on a rack rattled.

Yeotmal district.

Rajur (isoseismal III ?).

Stationmaster, G. I. P. R.—One shock for two seconds.

Pandharkawada (isoseismal III ?).

Tahsildar, Kolapur.—One tremor for two seconds.

Pusad (isoseismal III ?).

Tahsildar.—One slight shock felt by some people.

Kalamb.

Assistant Medical Officer.—One continuous trembling during which a sound as of a passing heavy goods train was heard. The shock was felt by persons at rest and doors and windows rattled.

Wun.

Tahsildar.—Several shocks were felt. In a few cases loose objects rattled. Hanging objects swung east-west and north-south. The observer's seat moved perceptibly.

Arni.

Y. R. Despande.—One slight shock.

Central Provinces.

Nimar district.

Bir.

Assistant Stationmaster, G. I. P. R.—Awakened from sleep.

Amir Ali.—One mild shock for ten seconds. Doors and windows rattled, hanging objects swung north-south and his chair was shaken.

Khandwa.

K. B. L. Seth, Deputy Commissioner, Nimar district.—The shock was not of much intensity.

Chulkhan.

Booking Clerk, G. I. P. R.—Two mild shocks lasting 60 seconds.

Burhanpur.

G. H. Dhara, Signaller, G. I. P. R.—Three slight shocks lasting 60 seconds. The platform lamps swung to and fro in a north-south direction. The bench on which he was sitting moved thrice.

BETUL DISTRICT.

Barbatpur.

M. Venkatakrishna, Stationmaster, G. I. P. R.—One trembling felt for four seconds. It was accompanied by a rumbling as of an aeroplane flying at a low height.

Betul.

D. J. N. Lee, Deputy Commissioner, Betul district.—The shock was felt almost by all throughout Betul district but it was not strong. Small loose objects were thrown down and doors and windows rattled. At Betul three shocks at intervals of a minute or two were felt. The roof of the D. C.'s bungalow and a glass pane rattled. His seat was shaken.

V. G. Mathews, Assistant Commissioner, Betul district.—Two shocks separated by an interval of five to seven seconds. Doors rattled and a peculiar vibration of the roof of his bungalow took place, at first causing a noise like that produced by a passing lorry. A few seconds after the noise was repeated with much greater intensity and a distinct trembling of the floor occurred.

Sub-Divisional Officer, Betul.—Three separate shocks separated by an interval of 2-3 minutes. The second was the strongest of the three shocks and it shook his chair, table and motor car. Pictures were tilted.

Stationmaster, G. I. P. R.—One shock for 60 seconds. Sounds as of a motor car were heard during the shock. Doors, windows and loose objects rattled.

Jambara.

Stationmaster, G. I. P. R.—One shock for three seconds.

Dharakhoh.

Stationmaster, G. I. P. R.—One slight shock for two seconds. Windows rattled.

Amla.

C. Fox, Loco Foreman, G. I. P. R.—One shock for four or five seconds. Hanging flower pots swung east-west.

Stationmaster, G. I. P. R.—One shock for 120-300 seconds. It was felt by persons at rest, doors and windows rattled, hanging objects swung east-west. The tremor was slight and could not be felt by persons moving about.

Chhindwara district.

Pandhurna.

Stationmaster, G. I. P. R.—One mild shock for two seconds.

Wardha district.

Pulgaon.

Stationmaster, G. I. P. R.—One shock felt by persons at rest, lasting 50 seconds. Doors and windows rattled and hanging objects swung.

Wardha.

K. A. Subramanie, Extra Assistant Commissioner.—One mild shock was felt.

Nagpur district.

Narkher.

Stationmaster, G. I. P. R.—One shock for two seconds. The office counter shook east-west.

Saoner.

Naib Tahsildar.—One shock felt by many persons. Doors and windows rattled, hanging objects swung east-west and the observer's seat moved.

Katol.

Tahsildar.—One. shock felt by persons at rest.

Nagpur.

Divisional Engineer, G. I. P. R.—A continuous tremor lasting ten seconds. The observer, who was standing on the verandah of his bungalow, felt as if he were on board a ship with a sloping deck.

G. Persad, D. S. Office, G. I. P. R.—He was on the first floor of the office and felt two distinct shocks for 210 seconds. A sound as of a motor car ready to start or an aeroplane flying overhead was heard. The doors and windows of the office rattled. Ceiling lights and fans swung in a circular fashion.

Buti Bori.

B. Kakde, G. I. P. R.—One continuous but moderate shock for 60 seconds. The station bell swung north-south.

Bhiwapur.

Tahsildar.—One shock felt by persons at rest.

Kuhi.

A. Habib.—One shock felt by persons at rest. Hanging objects swung and the observer's seat moved slightly.

Bhandara district.

Bhandara.

District Superintendent of Police, Bhandara.—One shock for 60 seconds. Doors and windows rattled very slightly. Hanging objects swung east-west. Loose objects were thrown down eastwards.

K. N. De, Tahsildar.—One shock for five seconds felt by persons at rest. Doors rattled and hanging objects slightly swung east-west.

Gondia.

M. L. Kapoor, Tahsildar.—One continuous shock for 120-180 seconds. Some persons asleep felt the shock. Tables, chairs, doors and windows rattled and *punkahs* swung north-south.

Paoni.

H. P. Varma, Range Officer.—Three shocks, of which the last was the strongest. Persons asleep felt the shocks. Doors and windows rattled.

CHANDA DISTRICT.

Warora.

Tahsildar.—One shock felt by many persons. Hanging objects swung in places for two or three seconds.

Stationmaster, G. I. P. R.—One continuous but slight shock for 30 seconds. Wagons and doors rattled and the observer's seat was slightly shaken.

Majri.

Stationmaster, G. I. P. R.—Five weak shocks for 180 seconds. Hanging lamp in a waiting room swung to and fro.

Balharshah.

Stationmaster, G. I. P. R.—One shock for 60 seconds. Doors and windows rattled and hanging objects swung N.E.—S.W.

Another report from a railway employee at Balharshah states that the shock lasted about 300 seconds. Doors and windows rattled and hanging objects swung N.E.—S.W. The observer's seat moved and some objects fell in a N.E.—S.W. direction.

S. Dougre, Loco Clerk.—One shock for 180 seconds felt by many persons. Hanging objects swung N.W.—S.E. and some loose objects fell south-east.

Bramhapuri.

Tahsildar.—One slight shock for a second or two.

Garchiroli.

Tahsildar.—All over Garchiroli circle the earthquake was felt for about 120 seconds. At some places four or five shocks were felt by some people but not by all. People sound asleep did not feel them. A few hanging objects swung slightly.

Sironcha.

Tahsildar.—One slight shock for a second or two. Hanging objects swung a little.

BALAGHAT DISTRICT.

Baihar.

S. G. Kamaisdar, Naib Tahsildar.—Ten to twelve continuous shocks accompanied by an unusual sound as of a motor passing by. Hanging objects swung north-south.

Balaghat.

A. Shrinivasam, Assistant Medical Officer.—One shock for five seconds, felt by persons at rest. The observer's seat moved slightly.

Drug district.

Bemetara.

S. G. Badhul.—One shock accompanied by a sound like that of a motor car at a distance. Doors and windows rattled. Hanging objects swung east-west and the observer's seat moved.

Drug.

B. A. Bambawale, Deputy Commissioner, Drug dist.—Three distinct tremors. Doors and windows rattled.

R. R. Thanjee, Executive Engineer.—One continuous shock. Doors rattled.

M. A. Khan, Canal Deputy Collector.—One continuous shock felt by persons at rest. Hanging objects swung east-west.

Tahsildar.—One shock. His attention as well as that of others was attracted by the rattling of doors and windows.

Balod.

Tahsildar.—One continuous shock felt by persons at rest. Doors rattled and a *punkah* swung slightly in a north-south direction.

Raipur district.

Baloda Bazar.

M. P. Davis.—Strong continuous tremors. A deep rumbling as of an aeroplane at a distance or of a large motor bus was heard coming from the east and moving westwards. The observer felt giddy in his chair. Doors and windows rattled for 180 seconds. Here and there in the village tiles fell from the roofs of mud huts.

Subdivisional Officer, Baloda Bazar.—A rumbling noise was heard during the shock, which was felt by many persons. Doors and windows rattled.

Raipur.

Subdivisional Officer, Raipur.—Two shocks preceded by a sound like that of a lorry moving fast and which changed afterwards into a dull sound. Windows and doors rattled for a long time.

V. S. Forbes, Vice Principal, Rajkumar College.—A trembling of fairly uniform intensity was felt by persons at rest. Doors and windows rattled. Water in an open concrete cistern, placed in an excavation in the ground, was rocked in an east-west direction and wetted both sides four inches above the level of the water. Hanging objects swung and the observer's seat moved. Some old plaster fell but new plaster did not.

Mahasamund.

P. W. Naidu.—One continuous shock preceded by a rumbling noise like that of a running train. Doors and windows rattled, hanging objects swung and books lying loose on a table were thrown down. Some plaster fell.

Dhamtari.

G. P. Bhargava, Tahsildar.—Three continuous shocks felt by persons at rest. Doors and windows rattled and hanging objects swung.

Madras.

Vizagapatam district.

Nowrangpur.

Deputy Tahsildar.—Two shocks for 30 seconds. Doors and windows rattled. The movement was north-south.

Rayagudda.

Deputy Tahsildar.—One slight tremor for 120 seconds. People at rest felt the shock, doors and windows rattled and the observer's seat moved slightly.

Gunupur.

Deputy Tahsildar.—One shock for 120 seconds felt by persons at rest. Doors and windows rattled, hanging objects swung north-south and the observer's seat moved slightly.

Jeypore.

Tahsildar.—One continuous shock for 180 seconds felt by many people. Doors and windows rattled, hanging objects swung north-south, and his table also moved in the same direction.

Civil Assistant Surgeon.—He felt one continuous shock for 180 seconds.

Headmaster, Board High School.—One continuous tremor for 180 seconds felt by most people. Doors rattled, hanging objects swung and his chair was shaken. According to a pleader the intensity was lowest in the middle and strongest at the beginning and end of the shock.

Koraput.

Revenue Divisional Officer.—One continuous tremor for 180 seconds felt by persons at rest. Doors and windows rattled, a motor car moved backwards and forwards and his seat moved. The roof of his house was slightly cracked.

Deputy Tahsildar.—He felt one shock for two seconds. Doors rattled, hanging objects swung and his chair was shaken.

Parvatipuram.

Clerical Staff, Divisional and Taluk Offices.—One continuous shock for 60 seconds was felt. Chairs were pushed in an east-west direction and a slight rumbling noise was heard. Persons lying on cots felt a reeling sensation. Doors and windows rattled slightly.

Bobbili.

Deputy Tahsildar.—One shock for five to ten seconds. He heard a sound as of a motor car running at a distance or of two grinding stones at work. The shock was felt by persons at rest, doors and windows rattled and hanging objects swung.

Vizagapatam.

Clerk, Revenue Divisional Office.—Two shocks for 60 seconds were felt. Hanging objects swayed east-west.

Clerk, Divisional Office.—A mild shock was felt.

East Godavari district.

Coconada.

C. D. T. Shore.—The chair on which he was sitting and a small tea table together with the floor on an upper storey of a large building swayed to and fro. Fans and lights swung to and fro. Trees and the corner of the bungalow had definite movements. The total duration of the shock was 180 seconds and the quake caused discomfort to people at rest.

B. A. Ram Singh, Meteorological Observer.—He felt half a dozen shocks for 120 seconds. Doors and windows rattled and hanging objects swung.

Mohamad Zindah, Collector's Office.—Half a dozen shocks for 120 seconds. His seat was shaken.

West Godavari district.

Ellore.

The Collector, West Godavari district.—One shock felt by persons at rest. Doors and windows rattled, hanging objects swung north-south and a glass tumbler on a table was thrown towards the south.

Kistna district.

Masulipatam.

E. C. Wood, Collector, Kistna district.—At 2-20 p.m., persons in a position of rest felt a succession of rocking movements like those on board a ship in a gentle swell. The shocks lasted 20-30 seconds. *Punkahs* swung N.W.—S.E.

Meteorological Observer.—One shock for 120 seconds. Doors and windows rattled and a reeling sensation was felt.

A. S. Thyagaraju, Noble College.—Two shocks were felt lasting about 180 seconds. The observer was on a cot, which appeared to roll east-west. Many people felt giddy. Some doors rattled and a pendulum clock stopped at 2-35 p.m. The tremor did not affect the town uniformly but appeared to have travelled along the north-eastern sector of the town. Houses falling in this zone experienced the shock in a greater degree than those in other parts of the town.

Guntur district.

Tenali.

T. E. Jeirsuri, Tahsildar.—Two shocks for 60 seconds. The second shock was more appreciable than the first. The observer's chair shook east-west.

Repalle.

G. Ramakanthacharyar, Tahsildar.—One shock for 60 seconds, felt by persons at rest. Doors rattled, hanging objects swung and the observer's seat was shaken.

Eastern States.

Sonpur State.

Sonpur.

A. N. Sarkar.—He felt the shock at 2-15 p.m. (I. S. T.) for 120 seconds. It was preceded by a rumbling noise. Loose tiles on the roof rattled. Hanging objects swung east-west.

ATHMALIK STATE.

Athmalik.

S. Ghosh, Chief Medical Officer.—He felt one continuous shock at 2-30 p.m. (Railway time) lasting about 180 seconds and heard the 'sound of a running car on the roof of the building'. Loose objects rattled and hanging objects swung. Some people felt another shock in the evening at about 7-30 p.m. on the same day.

HINDOL STATE.

Hindol.

Medical Officer, Hindol State.—He felt three mild shocks for 300 seconds at 2-15 p.m. Doors and windows rattled slightly and hanging objects swung north-south. His seat was slightly moved.

NARSINGPUR STATE.

Narsingpur.

Hem Sen Gupta.—Two slight shocks at 2-20 p.m. (I. S. T.), one lasting about four seconds and the other two seconds. Loose objects rattled slightly.

BARAMBA STATE.

Baramba.

M. Naik, Superintendent, Baramba State.—He felt two shocks lasting about ten seconds at about 2-15 p.m. During the shocks a sound resembling that of a motor bus in motion was heard. Loose objects rattled. The shock was felt by persons at rest.

KALAHANDI STATE.

Bhawani Patna.

B. Mahanti, Dewan, Kalahandi State.—One shock for 120 seconds. A sound like that of a motor car in motion was heard before the shock. Windows and loose objects rattled, hanging objects swung and the observer's seat was shaken.

PATNA STATE.

Bolangir.

Bishan Singh, Superintendent of Police, Patna State.—One shock for 180-240 seconds. Doors rattled and his seat moved. A few tiles fell from the roof.

G. N. Hota, Sub-Inspector of Police, Sadar.—One mild shock for a few seconds. An unusual sound as of a motor car was heard simultaneously with the shock. Doors rattled and his seat moved N.W.—S.E.

Manoharpur, Bolangir P. O.

Baman Rath, Clerk, Settlement Office.—One continuous shock for 300 seconds. A rattling sound was heard. *Punkahs* in his office room swung to and fro. A slight crack appeared in one wall of the Settlement Officer's quarters.

Patnagarh.

D. C. Rai, Subdivisional Officer.—One moderate shock for 120 seconds. The roof and doors rattled and his seat and chair moved.

P. K. Chopdar, Second Officer.—A *punkah* swung north-south.

BAUD STATE.

Baudgarh.

G. C. Misra.—Two shocks lasting 155 seconds. The first was the stronger of the two and lasted about 90 seconds, after an interval of 25 seconds a milder second shock was felt for 40 seconds. The shocks were not felt by persons sleeping but only by persons resting awake. Almirahs and light loose objects, doors and windows rattled slightly. Hanging objects swung N.E.—S.W. A lightning conductor on the top of a building 75 feet high shook perceptibly. Some people were unable to write properly as their hands began to shake.

DASPALLA STATE.

Daspalla.

B. N. Nayak, Dewan, Daspalla State.—One shock for 60 seconds. Doors and windows rattled, hanging objects swung and the chair on which he sat was shaken.

KHANDPARA STATE.

Khandparagarh.

P. K. Pujari, Superintendent, Khandpara State.—He felt a very mild shock lasting about 60 seconds at about 2-16 p.m. His seat moved. Hanging objects swung north-south.

NAYAGARH STATE.

Nayagarh.

Nilkantha Mahapatra.—He felt only one shock of slight intensity for 70 seconds. Many people doing office work did not feel the shock.

RANPUR STATE.

Ranpur.

B. Pahtanayak.—He felt three slight shocks lasting about 15 seconds. Hanging objects swung north-south.

Orissa.

BALASORE DISTRICT.

Bhadrak.

D. C. Das, Subdivisional Officer.—One shock for 120 seconds felt by persons at rest. Doors rattled, hanging objects swung north-south and the observer's seat moved.

Chandbali.

Wahed Ali, Meteorological Observer.—One shock for 120 seconds. Loose objects rattled, hanging objects swung N.W.—S.E.

Capt. D. J. Manfield, R.I.M., Port Officer, Orissa Ports, was afloat on the Dhamra river and felt no shock.

Cuttack district.

Kendrapara.

G. C. Chandra, Subdivisional Officer, Kendrapara.—Two shocks for 180 seconds. They were felt by persons at rest. Hanging objects swung and his seat moved.

Puri district.

General (Puri district).—The reports from the various police stations in Puri district state that a mild shock lasting about 60-180 seconds, was felt all over the district. Persons asleep or walking did not feel the shock. Doors, windows, tiles on roof rattled gently. Loose objects fell down in some places. Hanging objects swung either north-south or east-west. A report from Kakatpur Police Station states that a rumbling noise like that of a motor engine in action was heard during the shock.

Puri.

Subdivisional Officer, Sadar.—He felt two shocks lasting 60 seconds. Both the table and chair rocked east-west.

B. C. Nayak, Deputy Magistrate.—He was sitting on a chair inside the court room and felt two shocks for 60 seconds. His seat was shaken.

R. K. Mahapatra, Officer in Charge, Town Police Station.—According to him the shock lasted about 120 seconds. Persons lying on bed and those who were standing or sitting felt slight jerks. Persons asleep did not feel the shock. Hanging objects swung east-west.

Khurda.

Subdivisional Officer, Khurda.—He was working in the court room and felt one continuous shock for about 45 seconds. His table moved east-west and he felt giddy.

Ganjam District.

Surada.

Tahsildar.—Two slight shocks, of which the first lasted 15 and the second 10 seconds respectively. Venetian windows rattled and a table shook a little.

Russellkonda.

One shock, lasting 15-20 seconds. Doors and windows rattled. Movement was east-west.

Aska.

One slight shock for less than a second.

Ganjam.

One shock causing doors and windows to rattle. Hanging objects swung east-west. Loose objects fell both east and west.

A brick wall collapsed and several walls were cracked. Two small cracks appeared over the Rushikulya river bridge on the Ganjam road.

Udaygiri.

R. S. V. Aiyer.—One continuous tremor, for 20 seconds. One felt as if one's legs trembled. Doors and windows rattled slightly.

Chicacole.

Aileen Georgeson.—Three shocks for one, three and one seconds respectively. The second shock was stronger than the others and caused doors, windows and loose objects to rattle.

Bengal.

NOAKHALI DISTRICT.

Sandwip Island.

K. M. Ali, Circle Officer.—One shock of moderate intensity felt by persons at rest. Doors and windows rattled, hanging objects swung and the observer's seat moved.

CHITTAGONG DISTRICT.

Chittagong.

Treasury Officer.—One mild shock felt by the movement of chair and table.

S. B. Baul, Meteorological Observer.—Two light shocks for five seconds. Some persons at rest felt the shocks and hanging objects swung very slightly.

Assam.

LUSHAI HILLS.

Aijal.

Capt. E. G. Sutton, I.A., 1st Assam Rifles.—He felt one shock for 60 seconds. It was a gentle rocking motion and caused doors and windows to rattle very slightly.

According to S. V. Lloyd Rees, Esq., I.P., the shock felt at Aijal was very slight.

MANIPUR STATE.

Imphal.

Registrar to the Political Agent, Manipur.—Two shocks were felt, the first lasting about 45 and the second about 60 seconds respectively. A mild vibratory motion was felt during the interval between the two shocks. Some hanging objects swung north-south by the first shock and east-west by the second shock. Very narrow cracks appeared in some of the walls and arches.

Mr. C. Gimson, the Political Agent, was about 30 miles away from Imphal, to the north-west, at Makui Khulen, a village about 5,100 feet high, and did not feel the shock at all.

NAGA HILLS.

Kohima.

Meteorological Observer.—Two shocks lasting about 90 seconds were felt by persons at rest. Doors, windows and loose objects rattled.

SIBSAGAR DISTRICT.

Sibsagar.

A. Macdonald.—One continuous undulatory movement for 60 seconds.

LAKHIMPUR DISTRICT.

Hoogrijan.

R. G. Philips, Hoogrijan P. O.—Duration 120 seconds. One shock was followed by a slow elliptical motion of the ground, the major axis of the ellipse being north-south. The shock was mild and caused hanging objects to swing north-south.

Digboi.

E. P. Vachell, Resident Geologist, B.O.C., Digboi.—Duration 120 seconds and the more severe tremors occurred within a period of about ten seconds. Hanging lamps and fans swung.

SADIYA FRONTIER TRACT.

Sadia.

J. H. Crace, I. P., Political Officer, Sadiya Fr. Tract.—He felt two intermittent shocks, one lasting 120 seconds and the other 180 seconds, making a total of 300 seconds. Doors and windows, etc., rattled, and some vases were made to dance. The shocks were slight but prolonged.

DARRANG DISTRICT.

Mangaldai.

G. S. Guha, Subdivisional Officer, Mangaldai.—One continuous swinging movement lasting about 240 seconds was felt. The shock was felt only by a few persons at rest. Doors and windows rattled slightly and hanging objects swung north-south.

Tezpur.

B. Ghose, Tezpur.—One shock lasting about 90 seconds. Hanging objects swung N.W.—S.E.

CHAPTER XXVIII.

ISOSEISMALS II—III.

North-West Frontier Province.

PESHAWAR.

Meteorological Office, R.A.F.—Two shocks at about 14·20 hours lasting about 60 seconds. The shocks were felt by persons at rest, and were strong enough to make doors and windows rattle and hanging objects swing.

MALAKAND AGENCY.

The Assistant Secretary writing from Peshawar for the Chief Secretary to Government, N. W. F. P. stated that slight earthquake shocks were felt in the Malakand Agency (Swat Ranizai and Sam Ranizai, Swat State).

Punjab.

GUJRANWALA DISTRICT.

Gujranwala.

Khan Bahadur Malik Zaman Mehdi Khan, Deputy Commissioner.—A very weak shock of short duration. A similar shock was felt at Wazirabad.

MONTGOMERY DISTRICT.

Chichawatni Road.

A. P. F. Hamilton.—Two distinct tremors at 14·24 hours, each of them lasted two or three seconds. Bed vibrated and doors rattled.

MULTAN DISTRICT.

Multan.

R. J. S. Dodd, Deputy Commissioner.—Lamps and fans swung slightly.

BAHAWALPUR STATE.

Bahawalpur.

Assistant Colonization Officer, Bahawalpur Government.—One shock for three or four seconds. Hanging objects swung east-west.

LAHORE DISTRICT.

Lahore.

D. N. Chopra, Meteorological Observer.—One shock felt by persons at rest for two to three seconds.

Gurdaspur district.

Gurdaspur.

J. M. Shrinagesh, Deputy Commissioner.—A very slight shock.

Kalanaur.

Nazar Ali Shah.—One slight shock. Hanging objects swung slightly in an east-west direction.

Batala.

Ghulam Mohammad.—Two to three shocks for 30 seconds separated by an interval of 10 seconds. Felt by persons on roofs of houses. Hanging objects swung and *charpai* moved.

Kahnuwan.

Budha Mal.—One slight shock for a second.

Jullundur district.

Nakodar.

Tahsildar.—One shock for 30 seconds felt by persons at rest, especially on the upper storey of houses.

Phillaur.

H. C. Mital, Subordinate Judge.—Three or four shocks for ten seconds separated by intervals of half a second. They were felt by persons at rest.

Ludhiana district.

Ludhiana.

J. Khan, Deputy Commissioner.—Mild shocks on 15th and 20th January 1934.

Mandi State.

C. F. Upton, Assistant Private Secretary.—A very slight swinging of the electric light chandelier in a north-south direction. The extent of the swing was about two inches.

Bilaspur State.

Bilaspur.

P. Khandulal, Diwan, Bilaspur State.– A feeble shock lasting about three seconds.

Suket State.

Sundarnagar.

Revenue Collector.—One slight shock felt by persons at rest, and moved the seat slightly. Duration five seconds.

Rajputana.

Jaisalmer State.

Jaisalmer.

J. Lal, Dewan, Jaisalmer State.—One shock of a very slight nature lasting about half a second. It was felt by persons at rest inside the house.

JODHPUR STATE.

Pachbhadra.

The Hakim, Pachbhadra.—One slight shock for five seconds.

Barmer.

The Hakim, Barmer.—One slight shock for a second or two.

SIROHI STATE.

Sirohi.

G. L. Macgregor, Chief Minister.—Two mild shocks for two seconds, felt by persons at rest.

PALANPUR STATE.

Deesa.

Meteorological Observer.—One mild shock for three seconds at 2-30 p.m.

Palanpur (isoseismal IV).

D. V. Paterah, Acting Wazir.—Two distinct shocks for about ten seconds. People felt them whilst either sitting, standing or lying on a bed. Doors and windows rattled. The shock was of very mild intensity and very slightly felt. The shocks were not noticed by all.

DANTA STATE.

Danta Bhavangadh.

R. B. Divanji, Dewan, Danta State.—One shock for 30 seconds. Windows rattled.

DUNGARPUR STATE.

Dungarpur (isoseismal IV).

Sardar Pratap Singh, Revenue Officer.—One slight shock lasting about 60 seconds. Doors and windows rattled and hanging objects swung. People lying on beds felt as if they were being pushed from underneath.

BANSWARA STATE.

Banswara.

Dewan, Banswara State.—A very slight earthquake for two seconds.

Sind.

KHAIRPUR STATE (PUNJAB STATES).

Khairpur Mir's.

Lady Doctor, Willingdon Hospital.—She was lying down reading and felt one shock for a second. Electric ceiling fan and light swung east-west.

States of Western India.

Sabar Kantha Agency.

Sadra, Sadra Division (Mahi Kantha).

M. B. Patel, Senior Deputy Political Agent, Sadra Division.—Two shocks felt by persons at rest for ten seconds. Loose articles rattled, and hanging objects swung east-west.

Bombay.

Kaira district.

Kaira.

R. S. Jayakar, Collector of Kaira.—Three very mild shocks for a few seconds, felt by persons at rest or sitting or standing in a position of quiet; giddiness was felt. Did not disturb sleepers.

Ahmadabad district.

Modasa.

G. A. Trivedi.—He felt one shock for two seconds at 2-30 p.m. He was sitting on a chair.

Broach and Panch Mahals district.

The Collector of Broach and Panch Mahals district, has kindly supplied the following consolidated report from the *taluqs* mentioned below :—

Godhra.

One shock for two or three seconds.

Kalol.

One shock for two seconds felt by persons at rest. Loose objects rattled slightly and hanging objects moved north-south.

Halol.

One shock for a second felt by persons at rest. Doors rattled and hanging objects swung 'round about'.

Jambusar.

One shock felt by persons at rest for 25-30 seconds. Windows and, at some places, loose objects rattled. Hanging objects swung north-south. Loose objects at some places fell either north or south.

Vagra.

Two shocks felt by persons at rest for two or three seconds. Hanging objects swung slightly.

Broach City.

One shock felt for a second by some persons at rest. Hanging objects swung north-south.

Broach taluq.

One shock for a second. Some loose objects were thrown towards the south.

Anklesvar.

One shock for two to four seconds, felt by persons at rest.

SURAT DISTRICT.

Surat.

D. A. Patel, City Magistrate.—Some people felt one shock for eight to ten seconds at about 2-22 p.m. Chairs moved, hanging objects swung and some clocks stopped. The observer, working in the court room, did not feel the shock nor did the other people inside the room.

T. P. Jetley, City Survey Officer.—One slight shock for two seconds. His chair was somewhat shaken.

Hazur Mamlatdar, Collector's Office.—He felt one continuous shock which was felt by persons sitting on chairs, which were shaken. Almirahs and loose paper racks on tables were observed to be shaking. The movement felt was north-south at first and later became circular.

Bardoli.

L. Crishnalal, Mamlatdar.—One shock for a second.

Jalalpur.

M. Manilal, Mamlatdar.—Three slight shocks were felt.

Bulsar.

V. N. Pradhan, Mamlatdar.—Two shocks for ten seconds. Clothes spread out on strings for drying shook east-west.

Chorasi.

M. G. Naik, Mamlatdar.—One slight shock for a second. Water in a trough spilled.

EAST KHANDESH DISTRICT.

Waghoda.

G. N. Bhargawa, G. I. P. R.—Three very slight shocks for two seconds. Windows, doors and loose objects rattled.

Mr. L. T. Gholap, District Magistrate, East Khandesh, writing from Jalgaon, reported that the shock in his district was felt at about a dozen places and was very mild as described below :—

Rawer.

Two shocks within five minutes, each lasting two seconds. The shocks were just strong enough to be felt by persons at rest and shook the floor and the walls of the room.

Chopda.

A very mild shock for a second or two. Floor appeared to shake slightly and clothes on pegs moved slightly.

Yaval.

One very mild shock for five seconds. Hanging objects swung slightly.

Savda.

Stationmaster, G. I. P. R.—One slight shock for 30 seconds. Time 14·20 (I. S. T.). It was felt by persons at rest, hanging objects swung east-west and his seat moved east-west.

Edalabad.

One slight shock for five seconds. Doors and chairs were slightly shaken.

Bhusawal (isoseismal IV ?).

Sub-Registrar's Office.—One shock felt for two seconds, causing the flanks of the windows to rattle.

People's Co-operative Bank.—One shock lasting 65 seconds; it was felt by persons at rest. Windows, and doors shook and tables moved a little north-south.

Mrs. C. J. Bower.—One shock was felt. Windows and small vases on the piano rattled. Electric fans and lights swung a little.

P. D. Patil, D. V. S. Office, G. I. P. R.—One continuous but slight shock for three or four seconds, felt by persons at rest. Doors and windows rattled, hanging objects swung east-west and his chair rocked east-west. Some loose objects fell.

S. V. Tailang, G. I. P. R.—One mild shock for 420 seconds. Windows rattled. Up platform shed swung north-south, a picture frame on a wall on that alignment swung north-south and the overbridge moved in the same direction. His chair was shaken.

Erandol.

One slight shock for two seconds. Hanging objects swung north-south.

NASIK DISTRICT.

Satana.

Mamlatdar.—At Jayakheda and Lohoner in the Satana taluq the shock lasted about two to four seconds. Loose objects rattled slightly.

Niphad.

Mamlatdar of Niphad.—Three shocks lasting about 180 seconds. The observer's chair was shaken.

Nasik.

S. G. Abaji.—He was sitting on the first floor of a house and felt a feeble shock lasting two or three seconds which caused him to shake twice or thrice. Doors and windows and loose objects rattled a little and hanging objects swung slightly. Time 2·15 p.m.

Mr. Dalvi, Pleader.—He felt one mild shock for two seconds. Hanging objects swung east-west. Time 2·15 p.m.

Nasik Road.

H. L. Khare, Cabinman, G. I. P. R.—One slight shock for 180 seconds. Time 14·19-14·21 hours. Window shutters made some noise, lamp wires oscillated and an empty tin fell down from the table towards the north.

Thana district.

Mamlatdar, Bassein.—He was lying on the bed and felt one shock for a second. Doors and windows rattled slightly.

Bombay.

N. Lishman (Sun Insurance Office, Ltd.).—He was on the top floor of a high five storey building on Altamount Road, Cumballa Hill, one of the highest buildings in Bombay. While resting in a deck chair, he felt, at about 2·15 p.m. a series of tremors. The second tremor followed the first after an interval of 60 seconds and was more intense. The third was the strongest and caused the ceiling fan and light to swing. He felt altogether six tremors over a period of seven to eight minutes. The tremors were at a speed of about three to the second and in all cases the movements commenced with very faint vibrations and reached a zenith in about ¾ of a minute. There was a definite period between each tremor when no movement at all was apparent.

K. N. Master, Taj Building, Gouali Trunk Road.—He felt three shocks lasting about 150 seconds at about 2·17 p.m. The intensity was strong enough to be felt by persons at rest, sitting as he was on a bed, and to cause hanging objects to swing.

Dharwar district.

Dharwar.

E. T. Roger, Executive Engineer.—Two shocks could only be felt by persons lying on the bed. Two side mirrors of a dressing table vibrated.

Deccan States.

Capt. A. A. Russell, M.C., Secretary to the Agent to the Governor General for the Deccan States and Resident at Kolhapur in a letter to the Director, Geological Survey, stated that the authorities of the Kolhapur and the Deccan States intimated that no shock was felt in any of the States on the 15th January 1934.

He, however, received the following information from the Dewan of Sawantwadi and the State Karbhari of Kurundwad (Senior) :—

Sawantwadi (Savantvadi).

The water of the well known as Chandatali in the Sawantwadi town rose during the period from the 15th to the 20th January, 1934, ultimately reached the top level of the surrounding pavement and overflowed.

Kurundwad (Senior).

The water of some of the wells at Tikota near Bijapur stirred and was seen dashing on the western walls of the wells for three or four minutes on the 15th January 1934.

Hyderabad State (Deccan).

The Secretary to the Resident at Hyderabad kindly forwarded the following information :—

Aurangabad district.

Aurangabad.

One slight shock for three seconds. Water from a fountain rose and flowed out.

A slight shock was felt for 30 seconds at Bhokardan, 10 seconds at Jalna and 60 seconds at Paithan. Loose objects rattled and small pieces of roofing material fell.

Parbhani district.

At Hingoli, Borala, Umra, Maliwar and Babalgaon of Hingoli taluq, the shock lasted two or three seconds. Hanging objects moved to and fro. In some places the cooking utensils that were arranged one above the other fell down. A double storey house was observed shaking.

At Basmatnagar, Kankhar, Bhendegaon, Hatta Phala of Basmatnagar taluq, a slight shock was felt for two seconds.

At Kalamnuri one slight shock was felt for two seconds.

Nander district.

At Ardhapur and Nander one slight shock for two seconds was felt.

Warangal district.

At Mulag two mild shocks were felt. Doors and windows rattled and house seemed to be shaken.

At Yellandu a mild shock was felt for 120 seconds.

Gulbarga district.

No shock was felt in this district but water in the wells rose for two minutes at Korangal, and at Konkal and Chitanpalli of Yadgir taluq.

Mahbubnagar district.

At Pargi taluq noise of water in the wells of some villages was heard.

At Mahbubnagar water in the wells rose for one minute.

At Nagar Karnul loose objects rattled and water in the wells rose and fell.

Madras.

Guntur district.

Bapatla.

J. Gopalarao, Tahsildar.—Two shocks for three seconds causing a reeling sensation.

Chirala.

Deputy Tahsildar.—Two slight shocks for one minute. Tables and chairs were shaken.

Ponnur.

Deputy Tahsildar.—One slight shock for two seconds. A slight sensation was felt by persons at rest and the observer himself felt a very slight reeling of the head and a very slight jerk towards the table.

Tiruvottiyur (near Madras).

Thakore H. S. Kishen Singh, Kaladipet-Washermanpet Post, Madras.—He was sitting on an easy chair and his mother resting on a camp cot on the first floor of his house. Both of them felt a mild shock causing the chair and the cot to rock a little. A broad piece of wood suspended from the roof of the room swung like a cradle for 180 seconds. The exact position of the village he was in lies half way between Tiruvottiyur and Kaladiepet but close to Tiruvottiyur Police Station. The shock was noticed by a very few people.

Bengal.

CHITTAGONG HILL TRACTS.

Rangamati.

M. R. Wenger.—A slight tremor followed by a strong shock lasting about 30 seconds. A small bookstand oscillated east-west.

Burma.

YAMETHIN DISTRICT.

Yamethin.

G. D. Stewart, Deputy Commissioner, Yamethin dist. A slight shock was felt in a very few villages of Yamethin township.

AKYAB DISTRICT.

Akyab.

Township Officer.—Two shocks for three seconds. Hanging objects swung north-south.

Superintendent, Post Office.—One shock for 50 seconds.

F. Ahmad, Meteorological Assistant.—Three slight shocks for five seconds. Hanging objects swung.

K. P. Chakraburty, P. W. Department.—Three slight shocks for five seconds. Hanging objects swung.

Telegraph Department.—Two shocks for 70 seconds. Hanging objects swung slightly.

Pauktaw.

Headman U. Tha Gyaw.—Two shocks for three or four seconds. The shocks were felt by persons at rest and hanging objects swung north-south.

Minbya.

Township Officer.—One very slight shock for two seconds. Doors and windows rattled.

Myohaung.

Village Headman.—Two very slight but continuous shocks for two seconds were felt at 4 p.m.

Kyauktaw.

Township Officer.—One continuous shock for 180 seconds. The shock was felt by persons at rest.

Buthidaung.

Township Officer.—Four or five shocks for 40 seconds felt by persons at rest at 4 p.m. Doors and windows rattled, hanging objects swung north-south and the observer's seat moved.

Maungdaw.

Assistant Township Officer.—Two slight shocks for three seconds.

ARAKAN HILL TRACTS.

Paletwa (Northern Arakan).

Head Clerk, Superintendent's Office.—One shock for 20 seconds. It was felt by persons at rest. Hanging objects swung north-south.

SAGAING DISTRICT.

Chaungu.

Mg Tin.—Two shocks for two seconds separated by an interval of two seconds. The shocks were felt by persons at rest.

LOWER CHINDWIN DISTRICT.

Monywa.

B. R. L. Carter, Deputy Commissioner, Lower Chindwin district.—A slight shock for half a second.

CHIN HILLS DISTRICT.

Haka.

Assistant Superintendent, Haka.—His wife felt one shock when she was roused from her sleep. Doors and windows rattled and her bed moved.

Falam.

Van Huron, Chief of Tashon Tribe.—One shock felt by persons at rest. Doors and windows rattled and the observer's seat was shaken.

NORTHERN SHAN STATES.

Loiseng, (Tawnpeng State).

V. C. Pitchford, Assistant Superintendent, Namshan.—Two or three shocks for 15-20 seconds. The shocks were felt by persons at rest.

MYITKYINA DISTRICT.

Laukhaung.

C. C. Fisher, Assistant Superintendent, Laukhaung.—One shock, at about (?) 1.8 p.m., for ten seconds. It was accompanied by a rumbling noise which lasted during the shock. Doors and windows rattled, hanging objects swung and the observer's seat moved.

Fort Hertz (Hkamti Long).

W. M. F. Gamble, Meteorological Observer.—One shock lasting about ten seconds was felt inside the bungalow, which is supported on a raised structure. People sitting on the ground outside did not feel the shock, during which doors and windows rattled and the bungalow vibrated slightly and creaked.

CHAPTER XXIX.

SHOCKS REPORTED OUTSIDE THE GENERAL LIMIT.

Burma.

The Sub-Postmaster of Myawaddy village, Amherst district, Burma reported that a shock was felt in the village. This is nearly 300 miles from the nearest limit at which the shock was certainly felt in Burma, with the thickly populated city of Rangoon intervening. It is doubtful whether the movement at Myawaddy had any relation to the earthquake shock.

South India.

Several reports of a shock were submitted from the west coast of South India. In the Preliminary Report, published in 1934, this was referred to as a sympathetic shock. A further perusal of the reports leaves some doubt whether the movement felt was certainly connected with the earthquake, and it is even more doubtful whether slight cracks or settlement in buildings in that locality were caused by the movement—after an earthquake such effects are noted even although they may have actually existed previously.

The area, at its nearest point, is some 300 miles from the southern limit of the general shock. There is, of course, the possibility that there was a local increase in intensity on this narrow coastal strip of recent unconsolidated sediments similar to the local increases in intensity which occurred at the mouths of the Godavari and Mahanadi rivers.

South Kanara district.

Mangalore.

Mr. E. M. Gawne, Collector of South Kanara, has supplied the following information as recorded at St. Aloysius' College, Mangalore :—The shock was recorded at 14.17 hours and the needle of the seismograph regained its usual calm after 15 hours. Father Ferroli felt one shock in his room. The Electric Power House, erected in 1933 on low-lying and comparatively soft ground near the railway station, was cracked in several places.

Cochin State.

Mr. H. R. Uzielli, C.I.E., Collector of Malabar district, writing from Calicut, stated that some persons indoors felt the shock at Cochin and nowhere else in the district. The shock is said to have lasted there for a few seconds and caused overhead electric fans to swing.

Cochin (Ernakulam P. O.).

R. G. Bristow, Harbour Engineer in Chief to Government, Madras.—A momentary shock. Some people felt a slight giddiness as if they were being rocked. (The Harbour Engineer's office, quarters and other new buildings on the reclamation

subsided an inch, for the most part the subsidence was even, but one of the quarters sank chiefly at the southern end, but this may be due to other causes.)

Travancore State.

Alleppey.

Tahsildar.—One not very strong shock was felt by persons at rest. Water in tanks and wells was disturbed and in certain tanks moss and lichen were drifted ashore on the southern sides.

Other Shocks.

Several weak shocks were felt, in the early hours of the morning, by a number of people in the Anaimalai Hills, Coimbatore district and in some places of Madura, Ramnad and Tinnevelly districts of South India, between 11th and 15th January 1934. The shocks were just strong enough to be felt by those who happened to be awake at the time and in a very few instances to awaken people from sleep.

A shock of similar intensity was felt at Dibrugarh at 11-20 hours on 14th January 1934.

The Meteorological Observer at Fort Hertz in Upper Burma recorded minor tremors from 13th January 1934 for several days. According to him such tremors are very frequent there at that time of the year.

Some persons, in one or two places of Amherst and Mandalay districts of Burma, felt a feeble shock on the midnight of 15th January 1934 and the Subdivisional and the Township Officers of Toungoo, headquarters of the district of the same name, reported a slight shock there at 1 a.m. on 15th January 1934.

None of the above shocks appear to have any connection with the major shock that took place in Bihar on the afternoon of 15th January 1934, and may be regarded as of local origin.

SECTION D.—NEPAL.

(J. B. Auden.)

CHAPTER XXX.

NEPAL TERAI AND HILL TRACTS.

Introduction.

Before describing the damage incurred in Nepal, it is well to point out that the information was obtained by making three traverses :—one in the neighbourhood of Katmandu, map number 72 E; one to Udaipur Garhi, 72 J; and finally one to Dhankuta, Chainpur, Taplejung and Darjeeling, 72 M and N, 78 A. In spite of requests that the Hakims (Deputy Commissioners) of the various districts should send in reports as to the extent of damage in their territories, no information was forthcoming. Consequently reliance has to be made upon the three traverses, carried out along isolated routes. In places the discrepancies in damage between adjacent villages along those routes were sufficiently large to prevent any confident differentiation of the area into isoseismals. If more time could have been spared and a wider area covered, these discrepancies would probably have almost balanced out and a more certain delineation of the isoseismals would have been possible.

In an abstract translation from a vernacular memorandum, No. 565, dated the 9th Aswin Samvat 1993 (24th September 1936) from the Nepal Government Office to the Nepalese Officer attached to the British Legation in Katmandu, the following details of damage in Nepal have come to light.

Regions.	Number of houses levelled to the ground.	Houses cracked.	Houses partly cracked.	Rest houses damaged.
Houses in the three principal towns of the Nepal valley, including surrounding villages.	12,397	25,658	17,684	492
Hilly tracts of eastern and western Nepal.	64,742	73,253	1,266	..
Terai of eastern and western Nepal.	3,754	5,610	2,884	..
TOTAL	80,893	104,521	21,834	492

It will be noticed that the number of damaged and collapsed houses in the terai is not very great. This is not to be explained as due to any paucity in the number of villages, but rather to the fact that the village houses in the terai are largely built of mud, or of bamboo plastered with mud. Such houses suffered less damage than the brick and undressed stone houses of the hilly tracts.

Isoseismal X.

Terai : Jaleswar.—It was reported in Sirha that the damage at Jaleswar, 19 miles E. N. E. of Sitamarhi, was very severe, and that houses had slumped extensively into the ground. It is probable therefore that a small portion of the Nepal terai lies within isoseismal X.

Isoseismal IX.

Terai : Jaynagar-Sirha-Muksar.—From the Nepal frontier, just north of Jaynagar railway station, is a belt of flat alluvial terai 18 miles in width. Jaynagar is approximately 230 feet in altitude, while Muksar, at the foot of the Siwaliks, lies on the 500 foot contour, so that the upward gradient of the terai is only 15 feet per mile towards the north. Sand vents were scarce between Jaynagar and the Kamli river but were prevalent around Sirha. At Sirha it was stated that the first movements were horizontal and were followed by destructive vertical vibrations. The *kutcha-pucca* houses at Sirha all collapsed during the second phase, but the mud-plastered bamboo huts suffered little damage. The wells were only slightly choked by sand. Sanding, fissures and slight faults in the alluvium occurred sporadically as far as the Siwalik hills, but were not common beyond Nipania (26° 48′ : 86° 21′). Fields at Koilpur (26° 41′ : 86° 17′) appeared to be extensively covered by sand, but two of them when measured proved to be affected only to the extent of 0·4 and 1·4 per cent. The only damage at Nipania was the occurrence of cracks in the *kutcha-pucca* houses. A small aftershock was felt by myself at this village at 06·03 on the 11th March 1934, when rapid vertical vibrations were accompanied by a low rumbling sound, sufficient to set all the village dogs barking earlier than their accustomed hour. Slight sanding was noticed as far as Amraha, beyond which it was absent on the gentle gravel slopes rising up to the Siwalik hills.

Terai : Jogbani-Dharan Bazar.—The width of alluvial terai between Jogbani and the Himalayan foothills is 25 miles. Jogbani is about 220 feet above sea level, while the foot of the Siwaliks is, in this part, at 1,000 feet, the average upward gradient to the north being 31 feet per mile.

Biratnagar (26° 28′ : 87° 17′) is a large town four miles north of Jogbani and is the headquarters of the Terai district between the Kosi and Ratua rivers. Most of the houses, built of wood with corrugated iron roofs, escaped severe damage, some being quite unaffected. The new granaries built of steel girders with corrugated iron roofs and sides were also quite undamaged. The official buildings were all *kutcha-pucca* houses of brick and mud binding. All were rendered uninhabitable and many collapsed.

Sand vents and fissures were rare around Biratnagar, but became worse at Sindhwari (26° 32′ : 87° 17′) and Mandheli (26° 36′ : 87° 15′). Sand vents persisted

as far as Hatia (26° 43′ : 87° 15′), but ceased on entry into the jungle-covered Bhaber zone.

Few of the houses by the side of the bullock cart track to Dharan were damaged, since most were built of corrugated iron. Several huts with thick thatched roofs were tilted over on account of the inertia of the superstructure.

In Dharan Bazar (26° 49′ : 87° 17′) the damage was very severe. 48 deaths were reported and in every house one or more walls had fallen. Destruction was equally severe in the bazar as in the upper town built upon a 250 foot terrace of gravels. Several walls of the Pindeswari temple, and the outer walls of the Bijapur temple were badly damaged. An ornamented pinnacle on the Pindeswari temple was bent over towards the E. S. E.

The houses in Dharan Bazar are badly constructed, having a core of undressed rounded boulders, taken from the river, faced on both sides by bricks set in a mud binding. At the time of visit reconstruction had already begun. Cross beams could be seen resting on narrow pegs driven into the verticals and loosely tied to them by thin strips of metal sheeting. The walls of these new houses were being built in the same manner as those that had collapsed, and a more unstable type of building could scarcely be imagined.

Hilly Tracts : Muksar-Udaipur.—The direct route to Udaipur *via* Muksar and the 2,200 foot col over the Mahamanda Danda (Siwalik Range) was not followed since it was stated to be highly dangerous on account of rock falls having rendered the Gobarjal (Dhauri) Valley impassable. An alternative route up the Rae *nala* was taken, up which were seen small rock falls in the soft Siwalik sands and clays. Minor sand vents occurred in the sandy bottom of the valley. On the return journey from Udaipur to Sirha one local coolie was persuaded to overcome his fear and to lead a way down the Gabarjal *nala* to Muksar. Rock falls were plentiful all the way down to Muksar, in four places having formed lakes that had completely blocked the narrow valley. Two of these lakes had emptied at the time of visit, while the larger of the remaining lakes was about 600 feet long, and, owing to silting, only about 25 feet deep. The volume of rock fall from the Siwalik sandstones which had dammed this lake may be estimated very approximately to have been 250,000 cubic feet. The second remaining lake was 300 feet in length and very shallow.

One and a quarter miles to the south of Muksar (26° 52′ : 86° 23′) the edge of a terrace of old, probably Pleistocene, gravels 40 feet in height had extensively collapsed into the plain below. This is illustrated in Plate 27, fig. 2, in which also may be seen rock falls in the Siwalik sandstones along the southern border of the Siwalik range.

At Risku (26° 58′ : 86° 26′) the damage was not extensive and most of the houses were inhabitable. This village lies at an altitude of 1,900 feet in a valley on a low terrace of river gravels, a situation where the damage might be expected to have been severe.

Udaipur Garhi (26° 57′ : 86° 32′) is the headquarters of the district of this name, but is only a small village, consisting principally of a temple, jail, police station, kutchery and official's quarters. 267 deaths were recorded from the district. The village lies upon the crest of a ridge of clays and argillaceous sandstones belonging to the Nahan stage, at a height of 4,560 feet. The houses are built upon a clay

soil cap which was formed at a time when the ridge was covered by forest. In contrast to the little damage incurred at Risku, Udaipur showed almost complete collapse. All the official buildings fell, while not a village house escaped severe damage or collapse. The jail prisoners were chained together and housed in a shelter built of sal timber and leaves. The buildings at Udaipur Garhi are constructed of bricks and irregular blocks of Nahan sandstones set in a mud binding. Monoliths of the temple fell over towards the N. N. E. and north-east.

The thin soil cap upon the Nahan sandstones was fissured and in one place along the scarp face of the ridge the sandstones were step-faulted along joint planes down towards the south-western scarp face. A boulder of sandstone resting half enclosed in a hollow in the soil was dislodged over a distance of 9 inches (23 cm.) towards the north-east.

The spurs to the north of Udaipur belonging to the Mahabbarat Dekh were everywhere scarred by rock falls of weathered gneisses, schists, and quartzites, (Plate 27, fig. 1).

Most of the neighbouring villages to the north also suffered damage. Complete destruction was said to have occurred at Quibhir, Bhalaidhara, Dumbri and Chiakamen.

Hilly Tracts : Dharan-Tambur river.—The path between Dharan Bazar and Dhankuta ascends over a pass 4,500 feet in height through an outcrop of shattered vitreous quartzites. Rock falls were abundant in these quartzites on both sides of the pass (Plate 26, fig. 2), one on the north side blocking the path for a distance of about 100 yards.

Isoseismal VIII.

Terai : Raxaul-Birganj.—Between Raxaul and Amlekganj the chief means of communication is the 2½ foot gauge Nepal Government Railway. A bullock cart track runs alongside the railway, and was used by motor cars after the railway had been put out of action. Birganj is the headquarters of this railway. The station, the *pucca* houses of the railway quarters, and the high water tower by the station were not damaged. Damage was worse in the case of the *kutcha-pucca* houses of the bazar, where several cases of collapse were noticed in walls orientated east-west. The piers of some of the bridges near Birganj were cracked and the line itself was considerably buckled. Fissures and sanding were extensive between Raxaul and Birganj, but became uncommon between Parmanipur and Amlekganj. No damage was noticed at Parmanipur either to the bridges or to the village houses.

Hilly Tracts : Bhimphedi-Chandragiri.—Sisagarhi is a village situated upon a N. E.—S. W. ridge. Many old and badly built houses collapsed, the walls running north-south being the most affected. The N. E.—S. W. walls of the Maharaja's private bungalow were cracked, the width of separation being up to 1cm. Two chimneys fell, one towards 100° and the other towards 140°. One of the N.W.—S.E. walls in the cook house of the Dak Bungalow collapsed.

From Sisagarhi numerous landslides were seen south of Bhimphedi on the northern slopes of the ridge culminating in hill 8297.

Kutchlijor: the north-south walls of some of the houses fell eastwards. Most of the houses were cracked.

Chitlang : at Chitlang there was considerable collapse, and one person was killed. The N. W.—S. E. walls were the most affected.

Hilly Tracts : North-west of the Nepal valley.—Thansing : some of the buildings were slightly cracked. The dharamsala was unaffected. A village one mile to the north of Trisuli Bazar (27° 56′ : 85° 08′), lying upon an alluvial terrace, was more severely affected than the town itself. Partial collapse was noticed in three houses, and most of them were cracked.

Gerkuta : the edge of the terrace of gravels and sands collapsed into the Trisuli river.

Syabru (28° 08′ : 85° 20′) : the travel permit did not extend as far as this village, which lies a day's march beyond Betrawati (27° 59′ : 85° 11′). It was reported in Betrawati that 35 houses collapsed in Syabru. This village lies at an elevation of 8,000 feet, 2,200 feet above the Langtang Khola, and probably therefore is not situated upon an alluvial terrace. It is difficult to account for the reported severity of the damage, and it is possible that the presence of cracks was considered to be a major catastrophe.

Hilly Tracts : Dhankuta-Chainpur-Taplejung.—Dhankuta (26° 59′ : 87° 21′) is the headquarters of the most easterly of the Nepal districts. The town is situated upon a north-south ridge between the Arun and Tamur rivers and lies at an elevation of from 3,500 to 4,150 feet. 161 deaths were reported from the district. The damage to Dhankuta was very uneven. The hospital and male and female jails collapsed completely, while the kutchery and Bara Hakim's quarters, which are higher up upon the ridge, were cracked so severely as to necessitate demolition. The walls orientated north-south collapsed more than those running east-west. In contrast to this damage, the main part of the bazar was practically unaffected, except for minor cracks. This is surprising since the bazar lies upon the same ridge as the official buildings, and, like them, appears to have been built mainly of brick and mud.

Two destructive landslides occurred, situated 5 and 9 miles north-west of Dhankuta and causing respectively 30 and 13 deaths. Many villagers were out on the hill-sides at the time of the earthquake cutting grass and were caught by the falls of mica-schists and gneisses.

At Pairibas and Legua Ghat parts of old walls fell, the main movements being east-west. At Kumal several houses were cracked, but there was no collapse. The soil cap was fissured on the steeper slopes.

At Chainpur (27° 17′ : 87° 20′) the damage was very slight. Two houses fell while some others were cracked, but the majority of buildings and the temples escaped completely.

At Nundhaki (27° 19′ : 87° 28′) there was little damage to the village itself, but numerous landslides were noticed in the neighbourhood, most of them being old slips that had been set in motion again by the earthquake. One slip 1½ miles N. N. W. of the village originated at the time of the shock.

At Dumahan (27° 22′ : 87° 37′) a few of the houses were cracked but the damage was slight even in the case of buildings situated upon the edge of the river terrace.

Taplegung (27° 21′ : 87° 40′) is an important village along the route into Tibet *viâ* the Tamur river and its tributary the Yangma Khola. Reports which reached Katmandu suggested that the town had been wiped out and that a volcanic

eruption had blasted away a large area of the mountain side. The only building which suffered severe damage was the jail. Both the compound walls built of brick and mud and orientated N. N. E.—S. S. W. collapsed, while the interior building of undressed boulders of phyllite also fell. Houses belonging to the Hakim and the master tailor were cracked as well as several in the bazar and two temples. Taken as a whole the damage was very slight. Taplejung is built upon chlorite phyllites of the Daling series (Auden, 1935, Plate 8), and it may be remarked that there are no volcanoes in the neighbourhood. An extensive area of landslip, about three square miles in area and lying from one to two miles north-east of the village, originated in 1927, presumably as a result of the heavy monsoon of that year which also caused the destruction of the railway bridge over the Gandak river at Chhitauni Ghat. Another area of slip occurs near Dokhu, about three miles E. S. E. of Taplejung and is said to have begun in 1924. The slips due to the earthquake are unimportant in this region and inferior in size to those which were initiated before it.

Fissures were formed as a result of the earthquake on the Angbung ridge.

Isoseismal VII.

Terai Amlekganj. From mile 17 on the Nepal Government railway to Amlekganj, the railway and *kutcha* road pass over jungle covered gravels. A few buckles in the line were noticed, but the damage was slight. Amlekganj was almost unaffected except for minor cracks. Sporadic sand vents were seen. The buckled railway line should be regarded as within isoseismal VIII, but Amlekganj itself may be placed in VII, since even the *kutcha-pucca* bazar houses were only cracked.

Hilly Tracts : Amlekganj-Bhimphedi.—From Amlekganj (27° 17′ : 85° 00′) to Bhimphedi (27° 33′ : 85° 08′) there is a *pucca road* suitable for heavy motor traffic. The road passes through a short tunnel over the Siwalik range at Churia Ghat, which was undamaged. One pier of the bridge over the Karra river collapsed and the traffic had to be diverted over an adjacent temporary bridge. Samri bridge was unaffected. Slight cracks were seen at Bhainse Dobhan, in a large brick house two miles higher up, and at Dharsing village. The rope-way from Dharsing to near Katmandu was undamaged, although the shock was violent enough to prevent people from standing.

Hilly Tracts : North-west of Nepal valley.—Nawarkot (27° 55′ : 85° 10′) is the capital of the district of that name. Brick-panelled houses were affected by some large cracks, but not severely enough to make most of the buildings unsafe.

Trisuli Bazar : the suspension bridge over the Trisuli river was undamaged. Some of the houses were cracked.

Betrawati (27° 59′ : 85° 11′) : in this village severe cracks were noticed, but not severe enough to necessitate demolition and re-building.

Hilly Tracts : East of the Nepal valley.—The villages on the east side of the Nepal valley beyond the Nagarkot ridge were almost undamaged. Naldun, Balinapati, Sirtibas and Upper Deopur were scarcely cracked. The houses in the lower Deopur village (27° 44′ : 85° 36′) were cracked somewhat more severely but not sufficiently to render them unsafe.

NEPAL (KATMANDU) VALLEY.

Introduction.

In describing the damage of the Nepal valley it has been thought advisable to depart from the normal procedure of treating each isoseismal area in the general narrative which includes India, since it is considered that the account would lose cogency by being divided up into separate sections each referred more to areas of similar apparent intensity in Bihar than to one another. The Nepal valley forms a unit which is best described in a continuous sequence.

The Nepal or Katmandu valley is an enclosed basin about 100 square miles in area and lying at an elevation of 4,500 feet. It is completely surrounded by hills except for the Pharping gap on the south side through which the Bagmati escapes.

The population of the valley is given in the 1920 census as 306,909, and the number of houses as 66,440. The death roll was about 3,400, or a little over one per cent. The number of houses which collapsed to the ground was 12,397, nearly 19 per cent. of the total. 25,658 houses (38 per cent.) were badly cracked. These figures refer to the whole valley; the percentage in isoseismal X naturally being greater and in isoseismal VIII less than the average.

The valley resembles that of Kashmir in that a basin within the mountains has been partially filled by Pleistocene and Recent fluviatile and lacustrine sediments. In the case of the Nepal valley, rejuvenation has caused the numerous branches of the Bagmati river to cut steep sided valleys in to these sediments up to a maximum depth of about 350 feet. The more general depth is about 150 feet. The present disposition of these sediments is therefore in the form of a series of flat terraces with intervening flat-bottomed valleys. The strata filling the basin consist of gravels, sands, sandy clay, a stiff blue clay and lignite. The basement of these river and lake deposits consists of a varied assemblage of pre-Tertiary ortho- and para-gneisses, schists, slates, granulites, quartzites and limestones. Spurs of pre-Tertiary rocks penetrate into the basin from Deochak to Kirtipur, from Sheopuri to Boddhnath and from Nagarkot to Changunarayan.

The principle towns, Katmandu, Patan, Bhatgaon and Sankhu, lie upon Tertiary and Quarternary sediments.

There are therefore two contrasted types of rocks:—the compact metamorphics and partially metamorphosed pre-Tertiary series; and the young unconsolidated fluviatile and lacustrine strata. The latter resemble the beds comprising the Gangetic alluvium, with the important difference that their disposition in the Nepal valley as terraces bounded by steep cliffs permits the ready escape of water by seepage, and therefore prevents the formation of water-logged quicksands. Hence the seismic phenomena associated with mobile alluvial quicksands, such as occurred in the Gangetic plain, were absent from the Nepal valley. Only one small group of sand vents was observed in the valley, in a field near Harisidhi, a village 3 miles south of Patan. Fissures were occasionally noticed, as along the eastern side of the parade ground at Katmandu, where slight faulting had thrown the alluvium down very locally to the extent of a foot. General subsidence of the ground, and tilting and slumping of buildings were entirely absent. The type of damage in the Nepal valley was similar to that at Monghyr and not to that in the central slump belt of North Bihar.

In spite of the absence of water-logged sands in the Nepal valley, there was a marked contrast between the apparent earthquake intensity experienced over the alluvial area and that manifested on the surrounding outcrops of harder rock.

The damage in the Nepal valley was in general slight in the case of houses built upon the pre-Tertiary rocks bordering the valley and forming inliers and promontories into it, while it was much worse to buildings situated upon the young unconsolidated sediments, (Plate 26, fig. 1). Isoseismals IX and X are completely confined to the alluvial tracts in the valley, while the outcrops of pre-Tertiary rocks are characterised by an apparent intensity between isoseismals VIII and IX.

Isoseismal X.

Isoseismal X encloses a narrow tract running E. N. E.—W. S. W. at the eastern end of the valley in which are situated the town of Bhatgaon and the villages of Khokna, Bagmati and Harisidhi. There was a 100 per cent. destruction of houses in the villages, and the few temples in them which did not actually fall, were cracked and distorted beyond hope of repair. The condition in the three villages mentioned above was one of such ruin that streets and alley-ways were completely blocked and their former alignments were often impossible to discern. The death rate was very high and bodies were still being recovered from the ruins at the time of visit one month after the earthquake had occurred. 354 people perished in Bagmati and Khokna alone.

In Bhatgaon there was about a 70 per cent. destruction of houses. Counts along parts of different streets showed the following percentages of collapsed houses :—100, 77, 83, 40. Some temples suffered less, and the famous Nyatpola, or Five-roofed Temple, which was built in 1703, escaped except for minor falls from the eaves of the roofs. The Vhairaba temple on the other hand collapsed completely. The extent of damage is manifest by a comparison of Plate 25, fig. 2, in the Memoir with the Plate on page 215 of Volume I of Landon's ' Nepal '. The contrast between these two photographs, taken from almost the same spot, establishes the extent of damage which did occur and which is not at first evident from an inspection only of the plate figured in this Memoir.

Many of the great pillars with molded capitals, structures which would be expected to have fallen on account of the inertia of the heavy mass at the top, remained upright. An example is the magnificent Bhupatindra Malla shown in Plate 25, fig. 2. Some pillars were, however, tilted slightly, such as that in front of the Dattatraya temple which was tilted towards the north, but in general these structures remained unaffected and are evidently very firmly embedded in the ground.

The houses which escaped collapse were built of well-shaped polished brick which had been properly baked and neatly laid together. The damaged houses were built, in general, of poorly baked bricks and laid with an excess of mud binding.

Isoseismal IX.

Isoseismal IX follows very approximately the boundary between hard rock and the alluvial sands, gravels and clays.

Katmandu.—Independent estimates by Colonel Smith, I.M.S., and myself indicated that about 25 per cent. of the houses in the town collapsed. For the most part the houses are built of badly baked brick with abraded corners and laid together with an excess of mud binding. The damage appeared to be worse in the slightly more elevated part of the town than on the slopes leading down to the east and west. North-south and east-west walls were equally affected. A badly damaged area was around the Hanuman Dhoka. The Jagannath temple was tilted over towards the south and a satellite temple near by towards the east, while the capital of the fine pillar (figured on page 128 of Volume I of Landon's 'Nepal') fell to the ground in a northwards direction. The top roof of the Pali temple fell towards the W. S. W. The famous Dharara, or Bhim Sen tower, is a brick monument which was ten storeys and about 160 feet in height. Five storeys collapsed as a result of the earthquake. It was reported in Katmandu that this tower was once even higher than ten storeys, and that two of them fell during the 1833 earthquake.[1] The double storey portico of the Tri Chandra College, which was built in 1918, collapsed to the east, smashing the compound wall, (Plate 24, fig. 1).

The large palaces of the ruling family of Nepal were badly affected. The walls of these palaces are thick but are built of poor materials with an excess of mud binding and with only a facing of mortar. The wings were the most severely affected parts of these buildings.

The east-west walls of the Singha Durbar Palace showed considerable collapse, particularly that on the south side which fell towards the south. The whole palace was badly cracked.

At the palace of General Sir Kaiser Sum Sher the north-south wings suffered most. Of eight brick pillars erected in the garden, intended for the training of creepers, seven fell. The directions of fall were to the north, north-west and south-east, and the acceleration calculated according to West's formula was 2,048 mm. per sec. per sec. The bandstand roof fell to the N. N. E.

Parts of the east-west walls of the palace of Sir Mohan Shum Shere collapsed. The Durbar Hall was very badly cracked, particularly at the arches. Jack arch plates were bent. A stone ball, two feet in diameter, was thrown to the ground from the roof at the south-east corner of the building, a horizontal distance of 120 feet towards the S. S. E.

The north wall of the palace of General Krishna Shum Shere was completely destroyed and the whole building was very severely damaged.

At the Legation compound the *kutcha-pucca* bungalows on the east side of the compound were only slightly damaged, a bungalow built at the end of 1933 being untouched. The houses of the Legation Doctor and of the Superintendent were the most affected, some of the walls collapsing. Chimneys in the Superintendent's house fell eastwards. Pillars in the garden of the British Minister fell towards the east and E. S. E.

The north and south walls of Mr. Kilburne's house partially collapsed. Pillars in the garden fell to the north and south, and indicated an acceleration of 2,044 mm. per sec. per sec.

[1] Bhim Sen committed suicide while a prisoner in 1839 on hearing that his wife had been compelled to walk the streets of Katmandu naked. Unless the Dharara was erected during Bhim Sen's life time, this report is inaccurate.

Patan.—As in the case of Katmandu, there was about a 25 per cent. destruction of the houses in Patan. New buildings of polished brick escaped the worst damage in the same manner as at Bhatgaon. Destruction was severe in the Theima Thola. The Matsyandrinath temple was completely broken, but the pillars supporting statuettes of the God's favourites remained intact.

The private palace of His Highness, the Maharaja, was badly damaged, his own compartments at the south-west end and the north wall collapsing. A decorative pot on the top of the south verandah fell to the ground in a S. S. W. direction. The zoo enclosure was quite unaffected although surrounded on all sides by damaged buildings.

At Thimi about 80 per cent. of the houses were cracked and 25 per cent. badly damaged. At Sankhu between 30 and 40 per cent. of the houses appeared to require complete demolition.

At Dharamtali, four miles north of Katmandu, the collapse of houses indicated an approach in apparent intensity to isoseismal X. About half the houses fell and many of the roofs lolled over towards the east. This village lies on the top of a narrow ridge of clays and sands, and may be considered to have shaken as if it were the top of a structure the total height of which was equal to the height of the terrace and buildings combined.

Isoseismal VIII.

The area enclosed within isoseismal VIII corresponds approximately with the outcrops of pre-Tertiary rocks. There were numerous small rock falls in the highly weathered pegmatites of the Sheopuri Lekh, but the crumbly and unstable nature of these rocks does not necessarily indicate any high intensity of the earthquake waves.

Pashupatinath, Boddhnath and Swayambhunath, three of the most sacred places of pilgrimage in Nepal, escaped severe damage.

Pashupatinath lies upon weathered schistose quartz-granulites and is well built of large cut blocks of stone. It was undamaged.

Boddhnath lies on clays probably derived from the weathering of the underlying basement rocks and was also undamaged.

Swayambhunath has the finest situation of any building in the valley, lying on the top of a hill about 300 feet in height above the general valley level. The hill is covered by loose boulders of quartzite and granulite which are certainly part of the solid rock of which the hill must be made. The temple itself was undamaged, but some of the satellite temples and the dharamsalas were cracked. Landon states (Vol. I, p. 38) that this temple was damaged in the 14th century by a violent earthquake and was repaired by Jyotir (died 1427) in the early 15th century.

The new hydro-electric dam erected above Sundarijal was uncracked and Nagarkot (27° 42′ : 85° 31′) was almost undamaged. The bungalow at Kakuni (27° 49′ : 85° 16′) on the other hand, was very badly cracked and had to be demolished.

LOCALITY INDEX.

(Only the localities in Part I and Sections A, B and D of Part II have been mentioned in this index.)

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INDEX.

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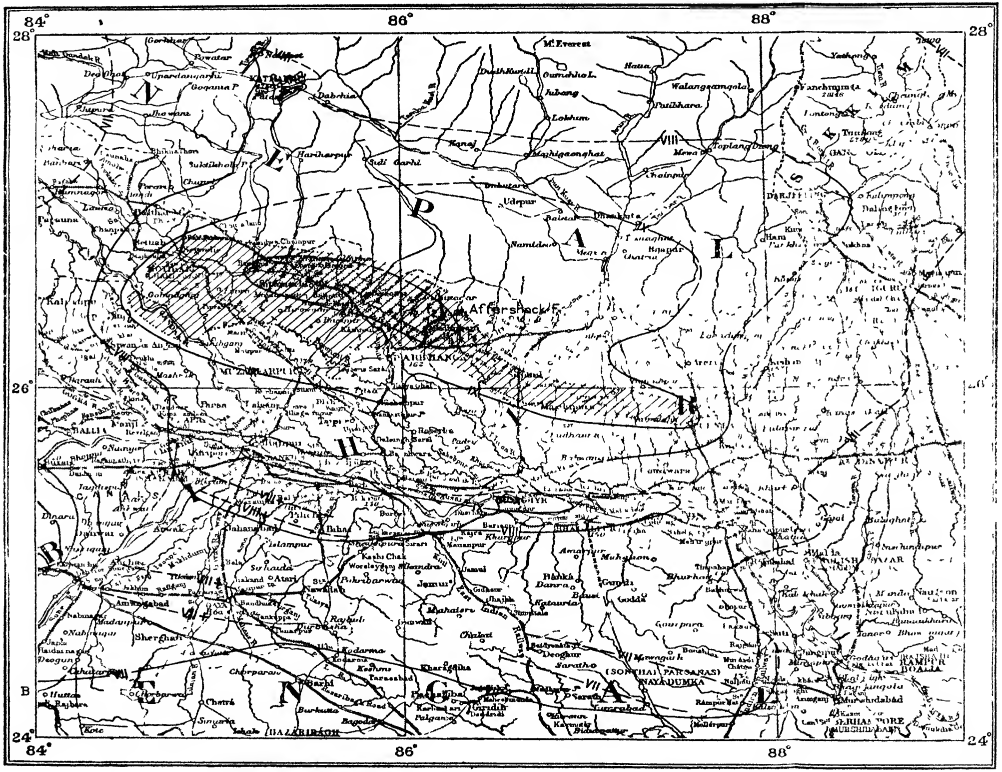


INDEX.

Isoseismal X

Slump belt

The isoseismal lines are based on the Mercalli scale

F_1—Focus of initial failure, main shock.

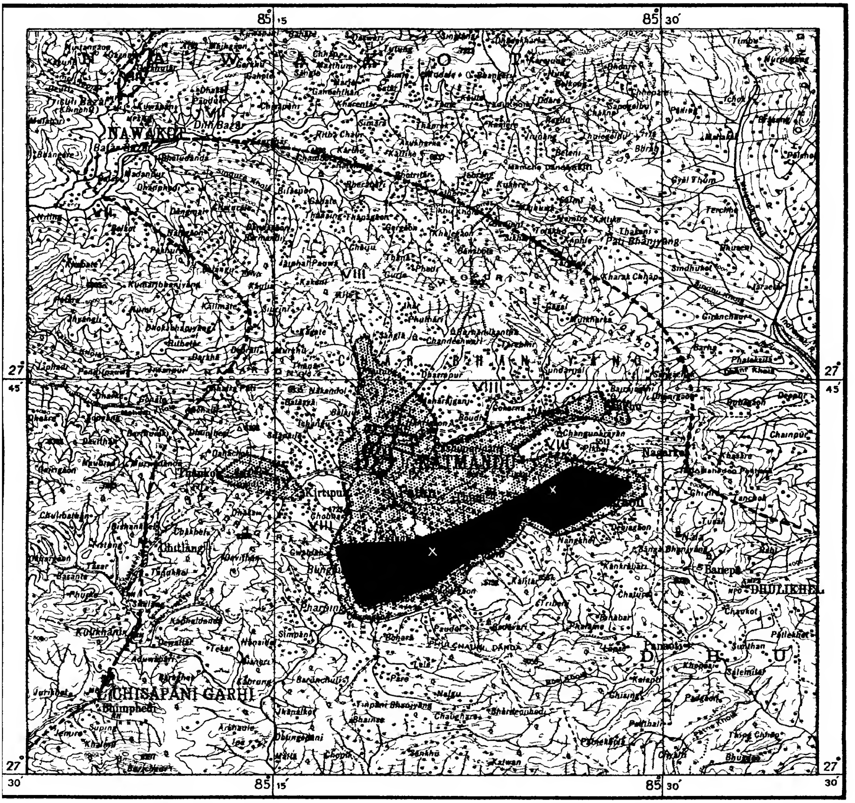
F_2– Focus of major failure, main shock

Aftershock F– Focus of aftershock of January, 19th

Scale, 1 inch = 32 miles.
1 2,000,000

THE HIGHER ISOSEISMALS OF THE EARTHQUAKE OF THE 15th JANUARY, 1934.

Based upon Survey of India maps 72 & 78, with the permission of the Surveyor General.



Isoseismal IX   Isoseismal X

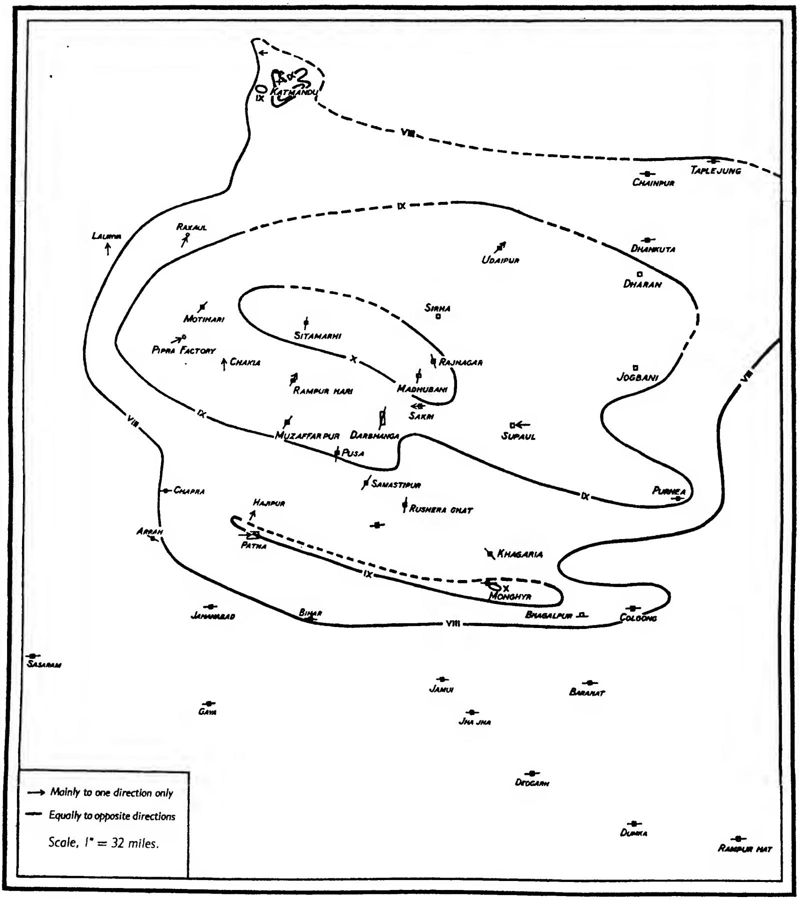
ISOSEISMAL MAP OF NEPAL VALLEY.

Scale, 1 inch = 4 miles.

Based upon Survey of India map 72 E, with the permission of the Surveyor General.

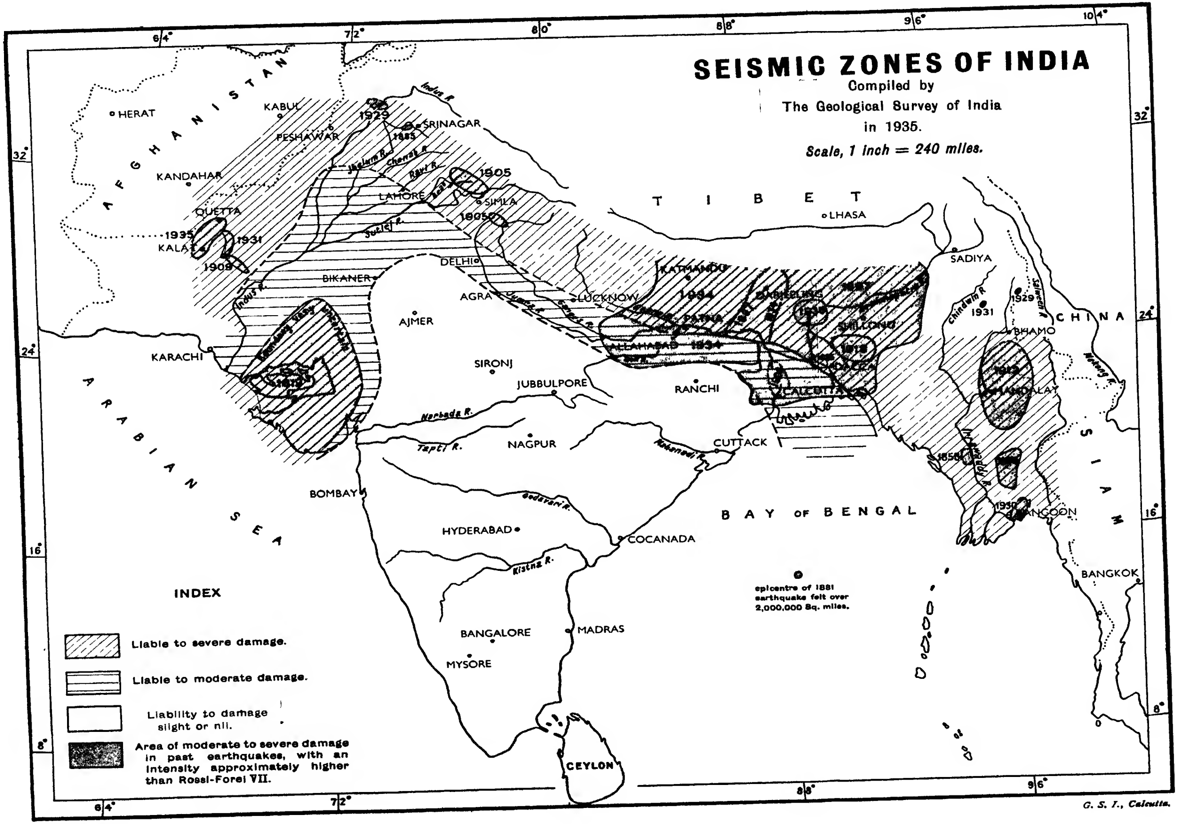
G. S. I., Calcutta.

Memoirs, Vol. 73, Pl. 4.



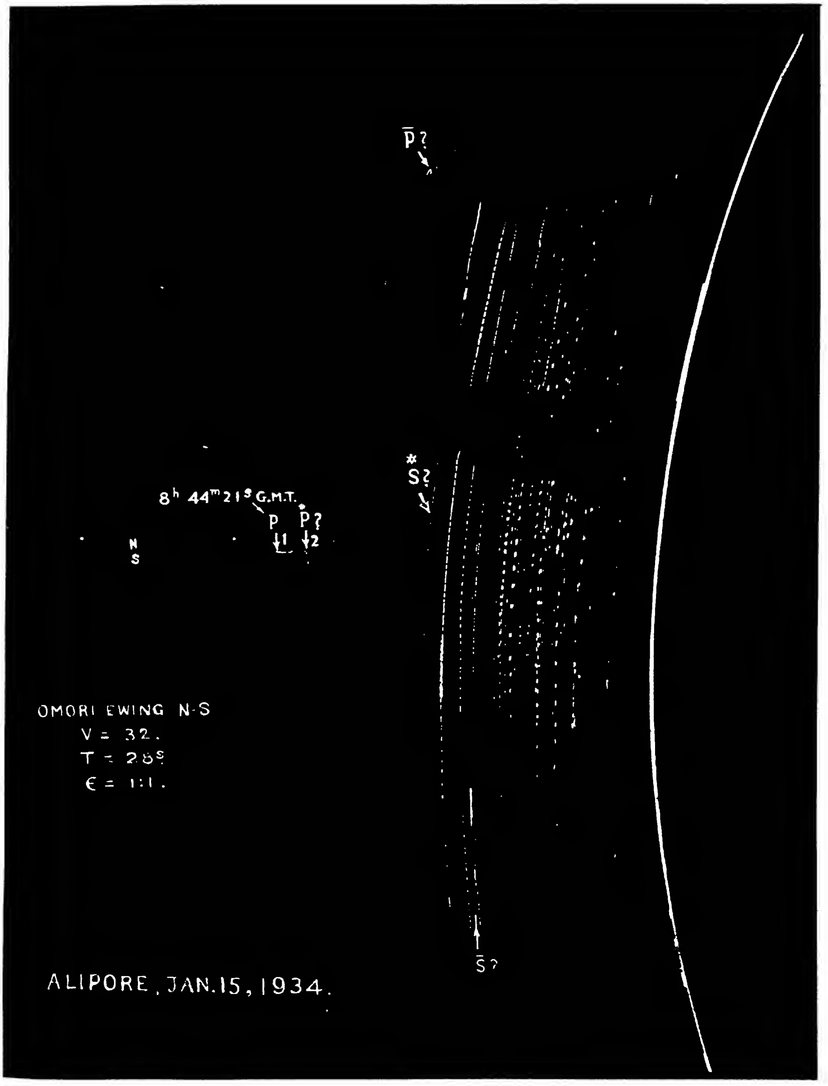
R N. Sawoo, del. G. S. I., Calcutta.

DIRECTIONS OF FALL OF OBJECTS DURING THE EARTHQUAKE OF THE 15th JANUARY, 1934.



A. K. Ghosh, del.

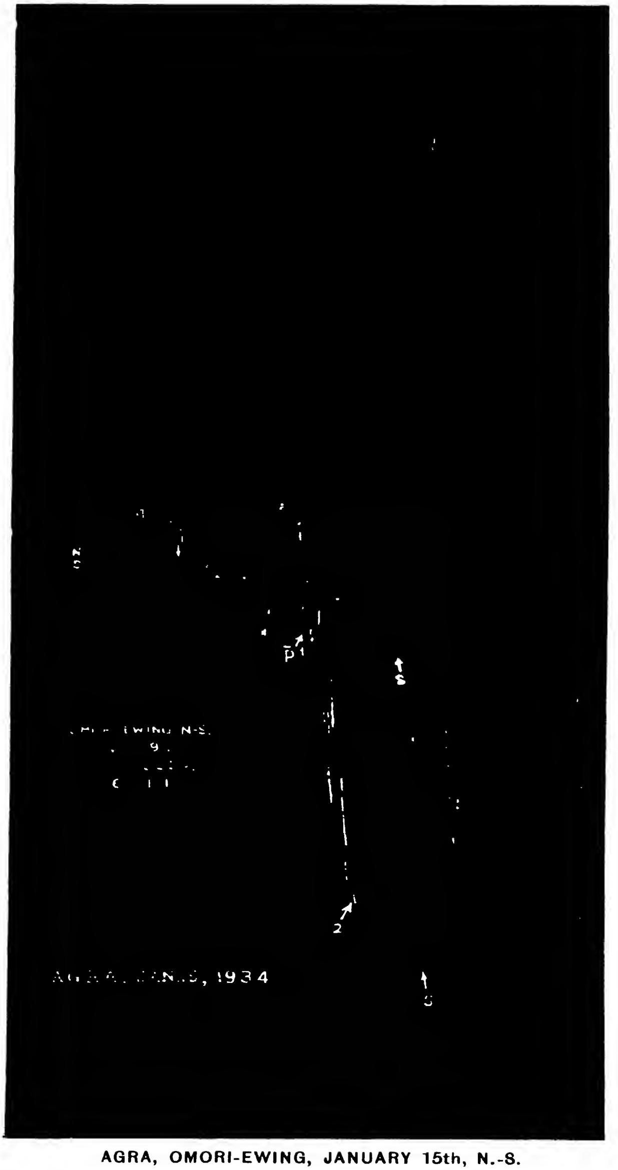
G. S. I., Calcutta.



SEISMOGRAM.

ALIPORE, OMORI-EWING, JANUARY 15th, N.-S.

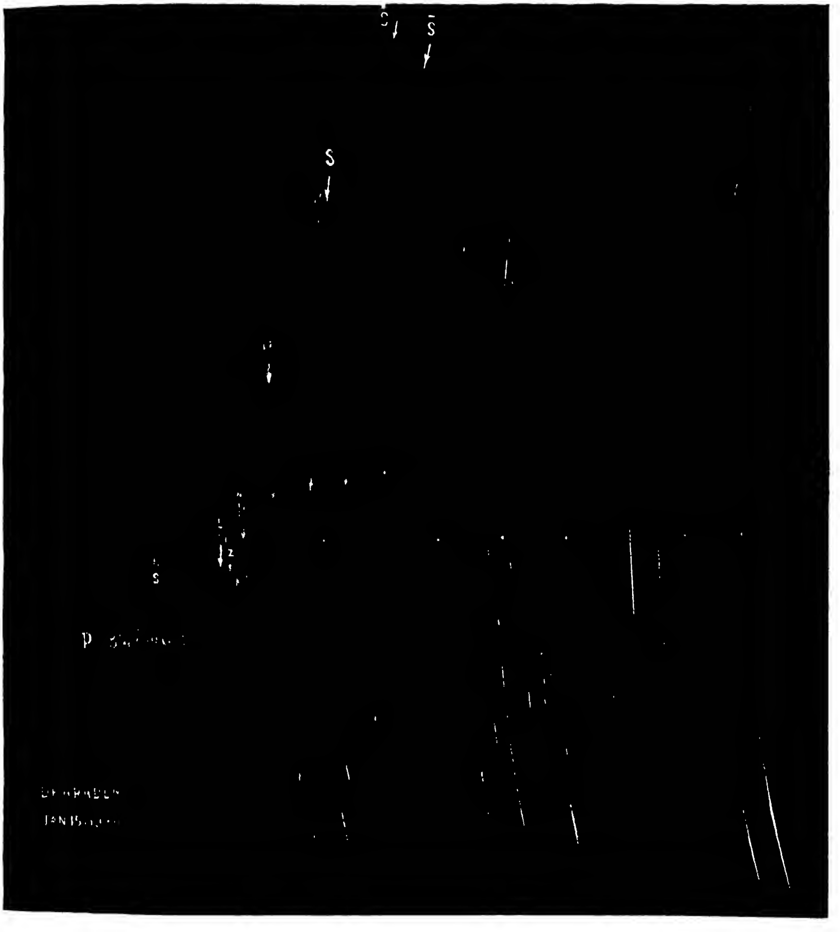
G. S. I., Calcutta.



AGRA, OMORI-EWING, JANUARY 15th, N.-S.

G. S. I., Calcutta.

Memoirs, Vol. 73, Pl. 10.



SEISMOGRAM.

DEHRA DUN, OMORI-EWING, JANUARY 15th, N.-S.

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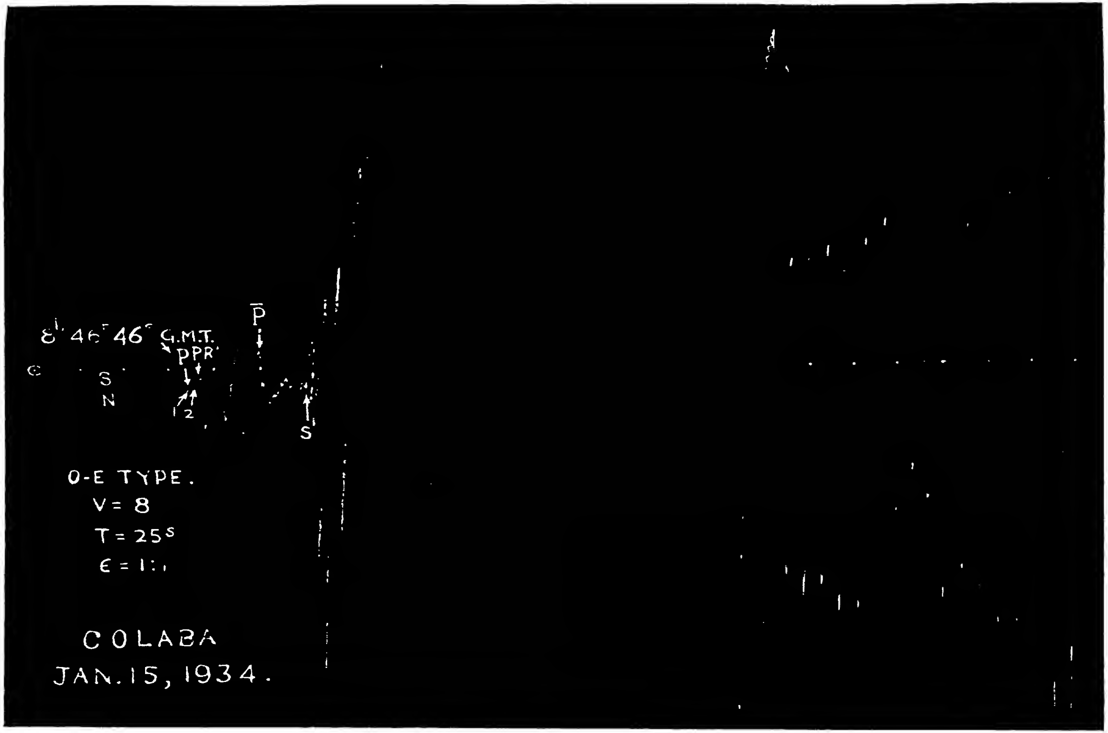

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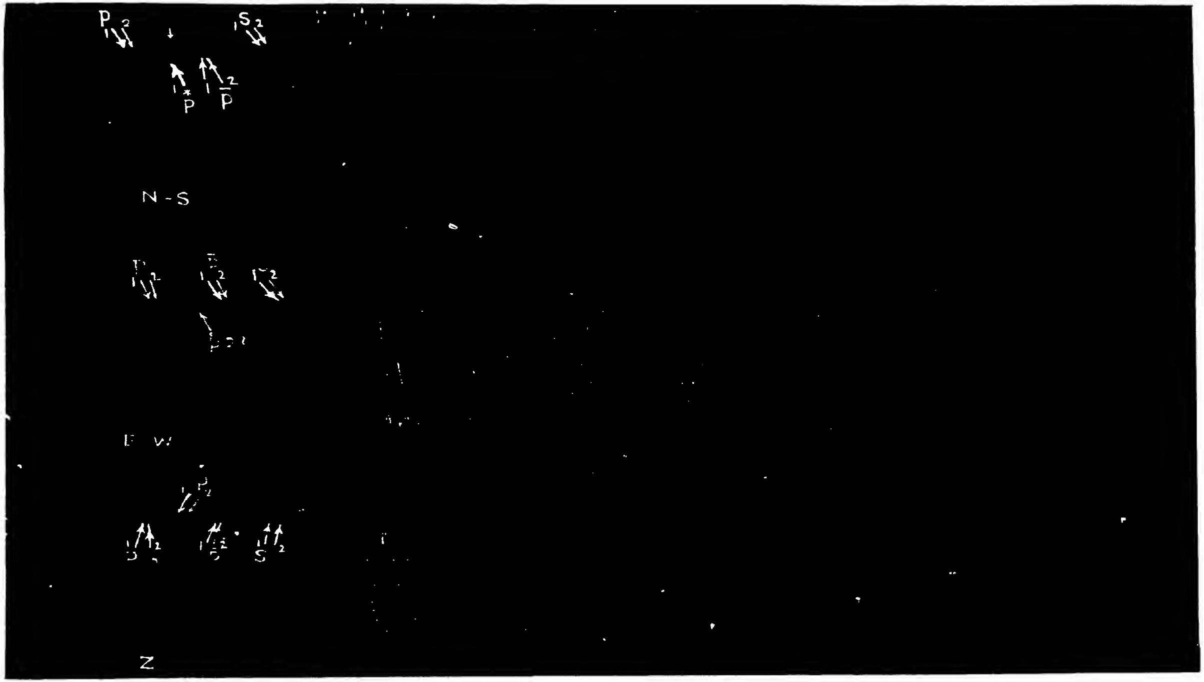
SEISMOGRAM.

2

3.



SEISMOGRAMS.

FIGS. 1, 2, 3. OORGAUM, OMORI-EWING, JANUARY 15th, 1934.

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FIG. 1.

FIG. 2.

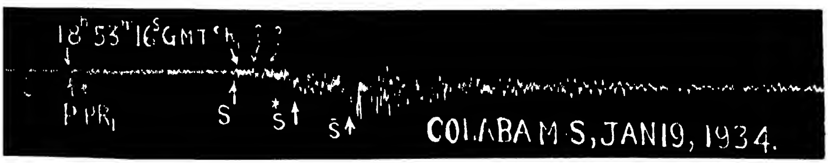

FIG. 3.

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SEISMOGRAMS.

FIG. 1. ALIPORE, OMORI-EWING, JANUARY 19th, E-W.

FIG. 2. A G R A, OMORI-EWING, JANUARY 19th, N-S.

FIG. 3. COLABA, MILNE-SHAW, JANUARY 19th, N-S.

FIG 1

FIG 2

FIG 3

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SEISMOGRAMS.

FIG 1 KOBE, JANUARY 15th N-S

FIG. 2 KOBE, JANUARY 15th Z.

FIG. 3. KOBE, JANUARY 15th E-W.

FIG. 1. MONGHYR BAZAAR, LOOKING WEST.

J. A. Dunn, Photos. *G. S. I., Calcutta.*

FIG. 2. BAZAAR SCENE, MUZAFFARPUR.

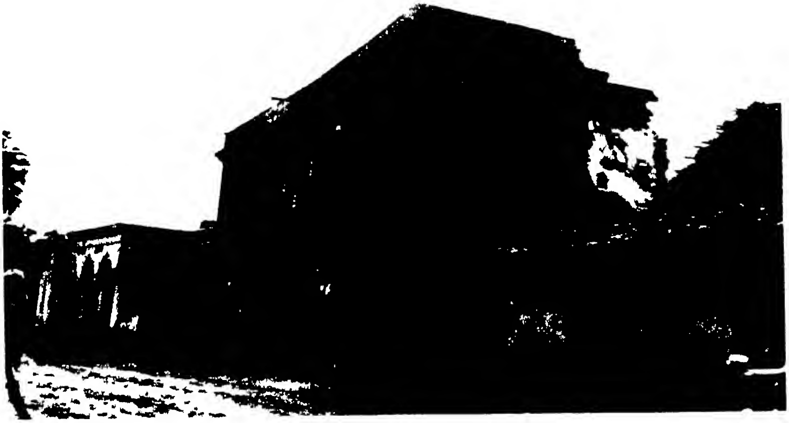
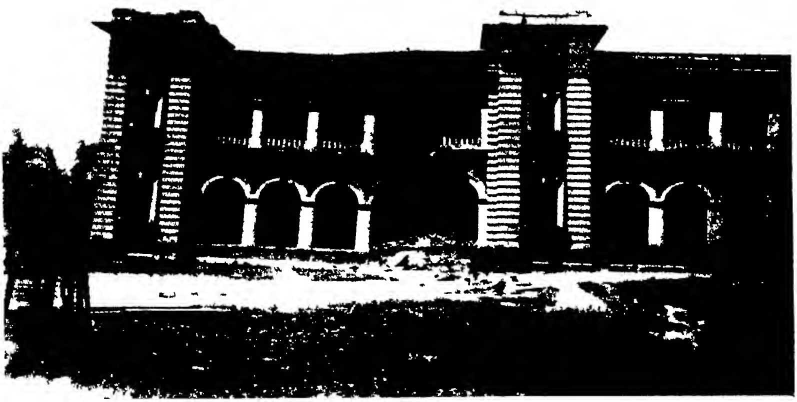


FIG 1 TILTED HOUSES, MADHUBANI



J A Dunn, Photos G S I, Calcutta.

FIG 2 CIVIL COURT, PURNEA, LOOKING WEST

IG I NEW INDIAN CLUB, PURNEA, LOOKING SOUTH

J. A. Dunn, Photos. *G. S. I, Calcutta.*

FIG 2 INTERIOR OF THE SAME BUILDING, LOOKING WEST

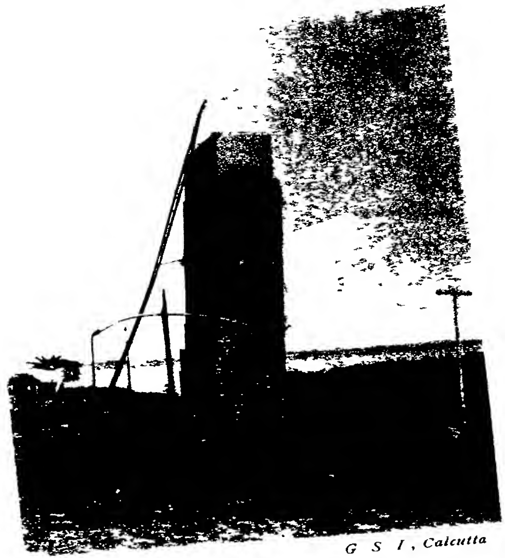
FIG 1 SUBSIDED EAST WALL OF DARBHANGA HOUSE, PURNEA, LOOKING NORTH

J A Dunn, Photos. *G. S. I., Calcutta.*

FIG 2 NORTH WALL OF CEMETERY, PURNEA, LOOKING WEST.

J A Dunn Photos

FIG 1 NORTH VERANDAH OF CIVIL COURT PURNEA

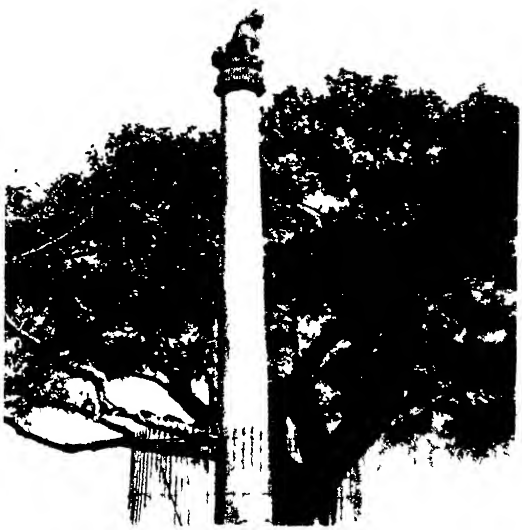


G S I, Calcutta

FIG 2 WATER TOWER, SULTANGANJ LOOKING N E

J A Dunn Photo

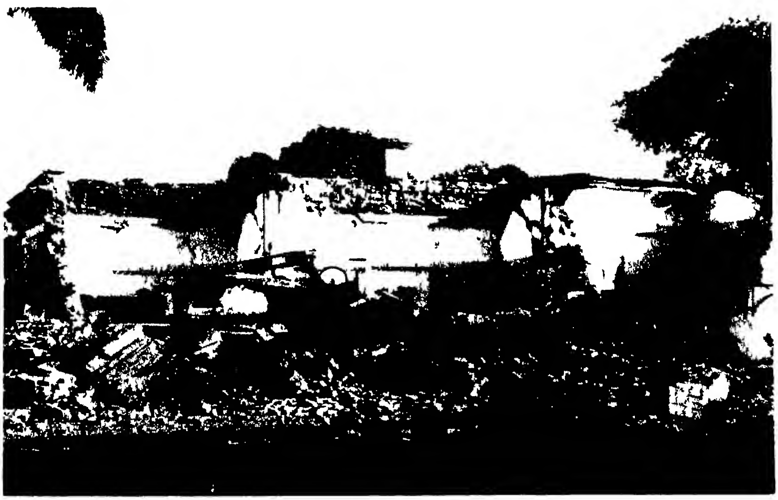
FIG 1 BAPTIST MISSION GATE MONGHYR LOOKING N N W



J B Auden Photo *G S I, Calcutta*

FIG 2 ASOKA PILLAR, LAURIYA, NORTH BIHAR

FIG 1 DIAGONAL WALL CRACKS VICTORIA ROAD JAMALPUR



J I Kly Photos

G. S I, Calcutta

FIG 2 COLLAPSE OF ARCHED ROOF, VICTORIA ROAD, JAMALPUR

FIG 1 THEIMA THOLA, PATAN, NEPAL VALLEY.

J. B. Auden, Photos. *G. S. I., Calcutta*

FIG. 2. THE DURBAR SQUARE, PATAN, NEPAL VALLEY.

FIG 1 TRI-CHANDRA COLLEGE, KATMANDU, NEPAL VALLEY

J. B Auden, Photos.

G. S. I, Calcutta.

FIG 2 HANUMAN DHOKA, KATMANDU, NEPAL VALLEY

FIG 1 NYATPOLA TEMPLE BHATGAON NEPAL VALLEY

J B Auden Photos *G S I, Calcutta*

FIG 2 BHUPATINDRA MALLA, DURBAR SQUARE, BHATGAON, NEPAL VALLEY

FIG. 1. HARISIDHI, NEPAL VALLEY

J. B. Auden, Photos *G. S. I., Calcutta.*

FIG. 2. ROCK FALLS IN QUARTZITE, ABOVE DHARAN, EASTERN NEPAL.

FIG 1 ROCK FALLS IN DARJEELING GNEISS UDAIPUR GARHI EASTERN NEPAL

J. B. Auden, Photos *G. S. I., Calcutta*

FIG 2 ROCK FALLS IN SIWALIKS, NEAR MUKSAR, EASTERN NEPAL

Memoirs, Vol 73, Pl. 28.

FIG 1 SANDING ON MUZAFFARPUR-DARBHANGA ROAD, NEAR MILE 13

J. B. Auden, Photos *G. S. I., Calcutta.*

FIG. 2. SAND VENTS NEAR MILE 14, MUZAFFARPUR-DARBHANGA ROAD.

FIG 1. MOTIHARI. SLUMPING ALONG MARGIN OF THE LAKE.

J. B. Auden, Photos

G. S. I., Calcutta.

FIG. 2. STEP FAULTS, POLO GROUND, MUZAFFARPUR.

FIG 1 FISSURE NEAR COLLECTOR'S BUNGALOW, MUZAFFARPUR

J A Dunn, Photos *G S. I., Calcutta*

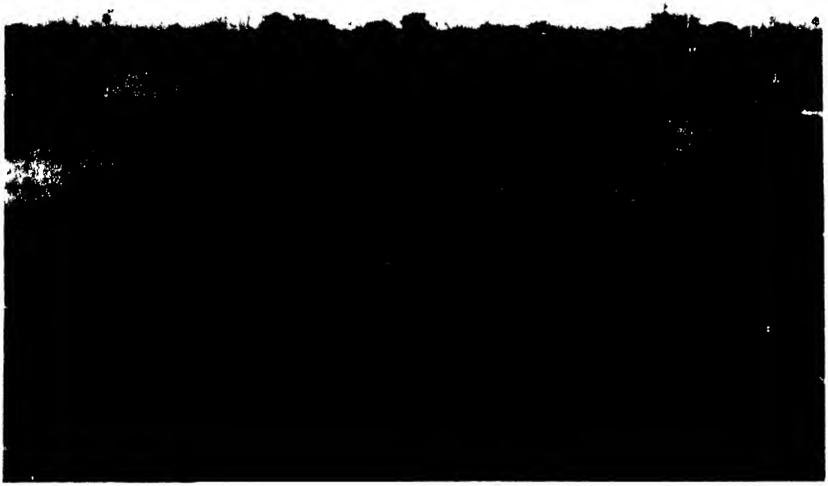
FIG 2 FAULTED ROAD, OPPOSITE JAIL, MUZAFFARPUR

J A Dunn, Photos

FIG. 1 A FISSURE, SITAMARHI. LOOKING N W

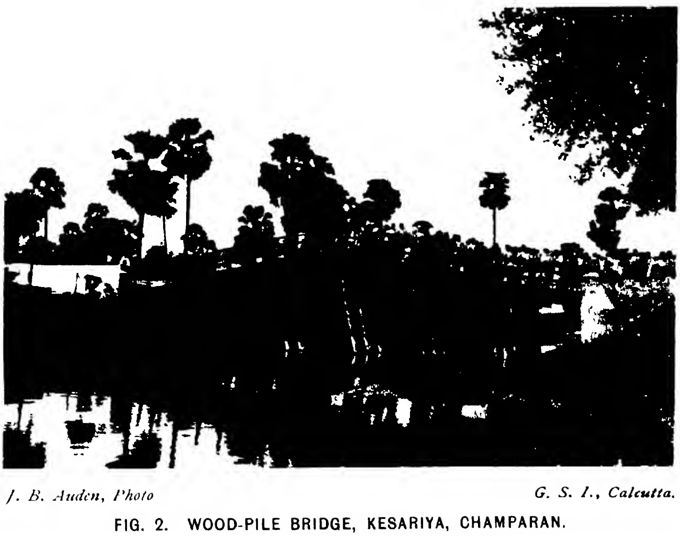
G. S. I., Calcutta.

FIG 2 RAILWAY TRACK, SITAMARHI, LOOKING WEST FROM BRIDGE



Courtesy of E. B. Rly

FIG. 1. ABOUT MILE 341 ON THE PURNEA-MURLIGANJ LINE, E. B. RLY.



J. B. Auden, Photo *G. S. I., Calcutta.*

FIG. 2. WOOD-PILE BRIDGE, KESARIYA, CHAMPARAN.

J B Auden Photo

FIG 1 ROAD BRIDGE ON PIPRA CHAKIA ROAD, CHAMPARAN

J A Dunn, Photo. *G S I, Calcutta*

BRIDGE OVER THE KALI-KOSI RIVER, CHAMPANAGAR, PURNEA DISTRICT

J. A. Dunn, Photo

FIG 1 SCREW-PILE BRIDGE ON THE SAMASTIPUR-DARBHANGA ROAD.

J. B. Auden, Photo *G. S. I., Calcutta.*

FIG. 2. BERNA BRIDGE, MUZAFFARPUR-DARBHANGA ROAD.

M. A. Ghosh Photo

FIG 1. INCHCAPE BRIDGE, MANJHI, 11 MILES WEST OF CHAPRA.

J. B. Auden, Photo. *G. S. I., Calcutta*

FIG. 2. RAILWAY BRIDGE, SITAMARHI.

FIG 1 E B RAILWAY BRIDGE NEAR FORBESGANJ

F b. Kly Photos *G S I., Calcutta.*

FIG 2 E B RAILWAY BRIDGE BETWEEN BATHNAHA AND JOGBANI

Date of issue.	Date of issue.	Date of issue.
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